



**FOUNDATION INVESTIGATION  
AND DESIGN REPORT  
DECEPTION CREEK  
CULVERT REPLACEMENT  
HIGHWAY 11  
TOWNSHIP OF CALDER  
AGREEMENT No.: 5010-E-0006  
GWP: 5149-11-00  
WP: 5112-09-01  
GEOCRES NO.: 42H-49**

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**PART 1: FACTUAL INFORMATION**

**1. INTRODUCTION**

DST Consulting Engineers Inc. has been subcontracted by Genivar who was retained by the Ministry of Transportation (MTO), Northeastern Region, to conduct a geotechnical investigation for the replacement of the Deception Creek culvert on Highway 11, 18.5 km west of Hwy 579, Township of Calder. This work was carried out under Agreement No.: 5010-E-0006, Detailed Design for the Replacement / Rehabilitation of Various Culverts.

This report addresses the field investigation, laboratory test program, factual report on conditions (Part 1) and recommendations for design and construction for the proposed culvert replacement (Part 2).

Geological information is available from published *Ontario Geological Survey Map # 5036* by the *Ontario Ministry of Natural Resources* for the Smooth Rock area, District of Cochrane. The map indicates a ground moraine formation with till and clay materials, subordinate landforms of organic terrain with peat and muck are also present. The topography in the area landform is mainly moderate local relief, the dominant land surface is undulating to rolling, and the subordinate organic terrain is plain like. The surface drainage conditions are mixed wet and dry within the ground moraine terrain, and wet in the organic terrain.

## **2. SITE DESCRIPTION**

The site is located on Highway 11, approximately 18.5 km west of Hwy 579 and Highway 11 intersection, Township of Calder, Cochrane Area. The structural site number is 39E-236.

Existing structure at this location is a 6.3 x 2.0 x 26.0 m three-cell timber box culvert. The culvert was identified to be in fair to poor condition and timber elements appeared to be rotting and checking with some elements missing completely. Significant settlement and rotation of the central support were also noted. The area was identified to be swamp/ muskeg. The depth of the cover is 2.0 m and minor erosion and loss of embankment fill were also documented.

The embankment slopes at this location are approximately 2.5H:1V to as steep as 1H:1V. Both sides of the embankment were sparsely vegetated and covered with grass (Figures 2.1, 2.2). The photographs shown in Figures were taken by MTO.



Figure 2.1 Culvert Inlet (facing northeast)





Figure 2.2 Culvert Outlet (facing northeast)



Figure 2.3 Culvert Buckling





Figure 2.4 Culvert Deteriorating



Figure 2.5 Inside View of Culvert

### 3. INVESTIGATION PROCEDURES AND LABORATORY TESTING

Site work was carried out between March 27<sup>th</sup>, 2011 and April 3<sup>rd</sup>, 2011 utilizing a CME 750 drill rig that was operated by DST personnel. A total of four (4) boreholes were advanced for the purpose of foundation design at this site, two (2) using hollow stem augers and diamond drilling techniques and other two (2) using hand augers. Boreholes were advanced to depths ranging from 3.3 to 20.7 m.

Two boreholes were advanced through the road structure at Station 20+005 offset 4.5 m right and at Station 19+995 offset 4.5 m left. Two auger boreholes were advanced at beyond the toe of slope near the existing culvert inlet and outlet at Station 20+005 offset 20.0 m left and Station 19+995 offset 18.6 m right respectively. The minimum number of boreholes, and depths and locations of boreholes were chosen according to the given specification in Request for Quotation (RFQ) by MTO.

The borehole locations are referenced to the MTO Station numbering system as indicated in the RFQ. The centreline of the existing culvert was assumed as Station 20+000. The ground surface elevations at the borehole locations were surveyed by DST personnel. At approximately Station 19+980 offset 23 m left a benchmark with an assigned elevation of 273.1 m was placed in a pole northerly near culvert. Borehole locations, stationing and benchmark location are shown on the Borehole Location Plan, Drawings 1. Table 3.1 summarizes the detail of borehole locations and depths.

Table 3.1 Detail of borehole locations

Borehole ID	Station	Elevation (m)	Depth (m)	Offset (m)
BH1	19+995	274.20	20.4	4.5 Lt
BH2	20+005	274.20	20.7	5.0 Rt
HA1	20+002	270.90	3.1	20.0 Lt
HA2	19+995	270.90	3.3	18.6 Rt

The fieldwork was supervised on a full-time basis by DST personnel who located the boreholes in the field, performed sampling and in-situ testing and logged the boreholes. Standard Penetration Testing (SPT) was performed in each borehole. Field vane test (FVT) was performed to estimate undrained shear strength of the cohesive soils. The soil samples collected during drilling were identified in the field, placed in labelled containers and transported to DST's laboratory in

Thunder Bay for further analysis.

Dynamic Cone Penetrometer Test (DCPT) was carried out in Borehole 2 from 16.1 to 20.7 m. DCPT test used 63.5kg hammer falling from a height of 760 mm and recorded number of blows to drive 300 mm cone penetration. DCPT test provided indication of soil type encountered at the depth.

Classification and index tests were subsequently performed in the laboratory on samples collected from the boreholes to aid in the selection of engineering properties. Laboratory tests included moisture contents, particle size analyses and Atterberg limits including plastic limit and liquid limit. A total of forty four (44) moisture contents, five (5) sieve analysis, six (6) particle size analyses and eight (8) Atterberg limit tests have been carried out for this assignment. Laboratory test results are presented in the Boreholes Logs (Enclosures 1 to 4), and Plots (Enclosures 5 to 10).

#### **4. DESCRIPTION OF SUBSURFACE CONDITIONS**

The subsurface conditions are presented based on the information obtained during field and laboratory testing.

The generalized stratigraphy of the existing embankment, based on the conditions encountered in boreholes, consists of surfacing (hot mix asphalt) overlying sand with crush gravel fill that is underlain by sand backfill surrounding the existing culvert. This fill is then underlain by clay and in some areas (Borehole 1) clay is underlain by gravel layer.

##### **4.1 Top Soil and Organic Soil**

A topsoil layer of up to 100 mm in thickness was encountered in hand auger-hole 1 and 2.

Organic soil was found in the hand auger holes 1 and 2. Thickness of organic soil was 0.6 – 1.2 m; this corresponds to maximum and minimum upper and lower boundary elevations of approximately 270.9 and 269.5 m respectively. The thickness of this layer in auger hole 1 and 2 was approximately 0.6 m and 1.2 m respectively.

##### **4.2 Asphalt**

Asphalt was encountered at the top in Boreholes 1 and 2 with a thickness of approximately 80 mm.

##### **4.3 Embankment Fill**

Embankment fill layer was encountered in Borehole 1 and 2 below the asphalt layer. Embankment fill layer was encountered at depths from 0.08 m up to 4.0 m in Boreholes 1 and 2; this corresponds to maximum and minimum upper and lower boundary elevations of approximately 274.2 and 270.3 m respectively. The thickness of this layer in Borehole 1 and 2 was approximately 3.6 m and 3.9 m respectively. Within the sand fill cobbles were noted during the drilling process. Grain size distributions of the fill material are reported in borehole logs (Enclosures 1 to 4) and plots (Enclosure 5 and 7). A pavement structure of two materials over the native soil (silty clay) was identified.

Directly below the asphalt, a fill of predominantly gravelly sand materials was encountered at Boreholes 1 and 2 at depths of between 0.080 and 0.5 m below ground surface; this corresponds to maximum and minimum upper and lower boundary elevations of approximately 274.1 and 273.7 m respectively. The thickness of this layer in both Borehole 1 and 2 was approximately 0.5 m. This

layer is roadbed granular layer. Gradation analyses conducted on a sample from Borehole 2 indicate gravel, sand and fines contents of approximately 36%, 56% and 8% respectively. Moisture content ranged from 7 to 9%. This material does not classify as Granular A meeting SSP 110S13 requirements.

Directly below this gravelly sand layer, a fill of predominantly loose to dense sand materials was encountered at Boreholes 1 and 2 at depths between 0.5 m and up to 4.0 m below surface; this corresponds to maximum and minimum upper and lower boundary elevations of approximately 273.7 and 270.3 m respectively. The thickness of this layer in Borehole 1 and 2 was approximately 3.2 m and 3.5 m respectively. Gradation analyses conducted on samples from Borehole 1 and 2 indicate gravel, sand, and fines contents of approximately 2 to 4%, 84 to 86% and 10 to 14% respectively. SPT values of 7 and 21 per 0.3 m indicate a state of variable compactness from loose to compact. An SPT value of 54 was encountered in Borehole 2, however, this is attributed to the presence of cobbles within this stratum. This material does not classify as Granular B, Type I meeting SSP 110S13 requirements. The moisture content of samples was between 3 and 14%.

In Borehole 1 wood debris was encountered within the fill at an elevation of approximately 271.1 m.

#### **4.4     Sand**

Silty Sand was encountered in Auger Hole 1. It was encountered at depths between 0.7 and 1.0 m below surface; this corresponds to maximum and minimum upper and lower boundary elevations of approximately 270.3 and 270.0 m respectively. The thickness of this layer in auger hole 1 was approximately 0.3 m. Gradation analyses conducted on sample from Auger Hole 1 indicated gravel, sand and fine contents of approximately 7%, 57% and 36% respectively. The moisture content of the sample tested was 43%

#### **4.5     Upper Silty Clay**

Upper silty clay was encountered in Boreholes 1, 2, and Hand Auger Hole 1, 2. It was encountered at depths between 3.7 and 6.0 m below surface in Boreholes 1 and 2; this corresponds to maximum and minimum upper and lower boundary elevations of approximately 270.5 and 268.2 m respectively. This material was also identified between depths of 1.0 and 3.1 m below surface in Auger holes 1 and 2; this corresponds to maximum and minimum upper and lower boundary elevations of approximately 270.0 and 267.9 m respectively. The thickness of this stratum was found



to be approximately 2.3 m as determined in Borehole 1 and 2. For Auger Holes 1 and 2 the thickness of this stratum is not determined as borehole terminus was reached within this stratum. In Borehole 1 trace wood and organics were encountered within the clay layer at elevation of 270.5 m.

Atterberg limit test carried out on samples from Boreholes 1, 2 and Auger Hole 1, 2 indicate this silty clay has a low plasticity with liquid limits and plasticity indexes from 28 to 34 % and 12 to 18 % respectively. In-situ field vane tests taken in Boreholes 1 and 2 indicate undrained shear strengths between 25 and 88 kPa with sensitivities ranging from 3 to 6 which indicates consistencies of firm to stiff. Gradation analyses conducted on samples from Borehole 1 and Auger Hole 1 indicated gravel, sand, silt and clay content of approximately 0 to 2 %, 13 to 30 %, 45 to 48 % and 24 to 37 % respectively. Moisture contents of samples ranged from 13 to 26 %.

#### **4.6    Clay**

Clay was encountered in Boreholes 1 and 2. It was encountered at depths between 6.0 and 9.1 m below surface in Boreholes 1 and 2; this corresponds to maximum and minimum upper and lower boundary elevations of approximately 268.2 and 275.1 m respectively. The thickness of this stratum was found to be approximately 3.1 m as determined in Borehole 1 and 2.

Atterberg limit test carried out on samples from Boreholes 1 and 2 indicate this clay has an intermediate to high plasticity with liquid limits and plasticity indexes from 49 to 61 % and 27 to 37 % respectively. In-situ field vane tests taken in Boreholes 1 and 2 indicate undrained shear strengths between 17 and 35 kPa with sensitivities ranging from 3 to 4 indicate consistencies of soft to firm. Gradation analyses conducted on samples from Boreholes 1 and 2 indicated gravel, sand, silt and clay content of approximately 0 %, 0 to 1 %, 10 to 16 % and 83 to 90 % respectively. Moisture contents of samples ranged from 46 to 74 %.

#### **4.7    Lower Silty Clay**

Lower silty clay was encountered in Boreholes 1 and 2. It was encountered at depths between 9.1 and 19.2 m below surface in Boreholes 1 and 2; this corresponds to maximum and minimum upper and lower boundary elevations of approximately 268.2 and 255.0 m respectively. The thickness of this stratum was found to be approximately 10.1 m as determined in Borehole 1. For Borehole 2 the thickness of this stratum is not determined as borehole terminus was reached within this stratum.

Atterberg limit test carried out on samples from Boreholes 1 and 2 indicate this silty clay has



a low to intermediate plasticity with liquid limits and plasticity indexes from 27 to 39 % and 7 to 19 % respectively. In-situ field vane tests taken in Boreholes 1 and 2 indicate undrained shear strengths between 19 and 42 kPa with sensitivities ranging from 1 to 4 indicate consistencies of soft to firm.. Gradation analyses conducted on samples from Borehole 1 and 2 indicated gravel, sand, silt and clay content of approximately 0 %, 0 %, 52 to 79 % and 21 to 48 % respectively. Moisture contents of samples ranged from 22 to 38 %.

#### 4.8 Gravel

Compact sandy gravel with silt was encountered in Borehole 1. It was encountered below a depth of 19.2 m; this corresponds to an elevation of 255.0 m. The thickness of this stratum is not determined as borehole terminus was reached within this stratum. Gradation analyses conducted on sample from Borehole 1 indicated gravel, sand and fine contents of approximately 40%, 35% and 25% respectively. An SPT value of 18 per 0.3 m indicates a state of compactness of compact. Moisture content of sample was 20%.

#### 4.9 Groundwater

The groundwater table was identified below the ground surface during the field investigation and visual identification of soil samples. The estimated depth of groundwater level below the ground surface elevation is given in Table 4.1. The water level in the creek at the culvert was at an elevation of approximately 270.6 m during the field investigation. The groundwater levels and water level at the culvert can be expected to vary with season and precipitation events.

Table 4.1 Depth of water table at boreholes

Borehole ID	Borehole elevation (m)	Water table elevation (m)	Depth of water table below the ground surface (m)
BH1	274.2	271.1	3.1
BH2	274.2	270.9	3.3
HA1	271.0	271.3	-0.3 (Standing Water)
HA2	270.9	271.1	-0.2 (Standing Water)

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**PART 2: ENGINEERING DISCUSSIONS AND RECOMMENDATIONS**

**5. PROJECT DESCRIPTION**

DST Consulting Engineers Inc. has been subcontracted by Genivar who was retained by the Ministry of Transportation (MTO), Northeastern Region, to conduct a geotechnical investigation for the replacement of the Deception Creek culvert on Highway 11, 18.7 km west of Hwy 579, Township of Calder. This work was carried out under Agreement No.: 5010-E-0006, Detailed Design for the Replacement / Rehabilitation of Various Culverts.

This proposed culvert is to be replaced by a two cell pre-cast box structure (2-3.0 x 2.4 x 27.5 m). The proposed culvert invert elevations for the inlet and outlet are 270.18 and 270.01 m respectively. A staged construction involving the installation of roadway protection and widening of the existing road embankment is the preferred method. The water table in the creek at the culvert was at an elevation of approximately 270.6 m at the time of the investigation

The generalized stratigraphy of the existing embankment, based on the conditions encountered in boreholes, consists of surfacing (hot mix asphalt) overlying crushed gravelly sand fill that is underlain by sand backfill surrounding the existing culvert. This fill is then underlain by clay and a deeper gravel layer.

This section presents interpretation of the geotechnical data presented in the factual report and presents geotechnical design recommendations and construction concerns for the proposed culvert replacement.

**5.1 Precast Concrete Box Culvert**

For this culvert replacement, a precast concrete box culvert is to be used. Open cut excavation has been considered for the replacement of the structure.

The design of the culvert must be in accordance with the Canadian Highway Bridge Design

Code CAN/CSA-S6-06 (CHBDC, 2006) and all relevant Ministry of Transportation specification and guidelines.

#### 5.1.1 Earth Excavation

An open cut operation along the proposed culvert alignment is proposed by MTO for the culvert replacement. This method of construction may result in traffic disturbances and may require temporary surface water ditch diversion and temporary support for traffic. It can more readily accommodate excavation of large boulders with this method, if encountered during excavation. As a minimum, the procedures should be in accordance with OPSS 902 "Construction Specifications for Excavating and Backfilling-Structures". Where temporary protection systems are required they shall be constructed in accordance with OPSS 539 "Construction Specification for Temporary Protection Systems" and Section 5.1.6 Roadway Protection.

If organic materials are encountered during excavation, the excavations to remove these organics and wood should be completed in accordance with OPSD 203.040. It is anticipated that the existing groundwater table will be above the invert level. Excavation below the water table can be undertaken by either dewatering of the excavation or in the wet without lowering the water table. If excavation is completed in the wet, any sub-excavated materials can be replaced with 19 mm Type I or II clear stone as defined in OPSS 1004.05.02. If fine materials are present beneath the clear stone a non-woven geotextile (OPSS 1860.07.05.01 Class II) with the filtration opening size (FOS) less than 135  $\mu\text{m}$  may be required for separation. No compaction is required for placement of the clear stone.

#### 5.1.2 Staged Construction

Staged construction has been identified by prime consultant, Genivar, as the preferred approach to maintain traffic during the construction of the culvert at this site. The proposed staged construction includes two (2) stages as given in Genivar Staging Drawings in Appendix B. Slope stability analyses for the proposed slope geometries have been conducted and are presented in Section 5.1.4 Embankment Design.

Stage 1 is a temporary lane diversion which involves temporary detour of traffic to the eastbound lane of 6.26 m width with existing side slopes, as well as the installation of level II roadway protection. Excavation adjacent the roadway protection is anticipated to an elevation of approximately 269 m to allow for placement of bedding materials. Use of temporary concrete

barriers will be required.

Stage 2 is a temporary lane diversion which involves temporary detour of traffic to the westbound lane of 6.26 m width with reinstated embankment foreslopes of 2H:1V in the upper and 1.5H:1V in the lower granular fill materials, as well as the installation of level II roadway protection. Excavation adjacent the roadway protection is anticipated to an elevation of approximately 269 m to allow for placement of bedding materials. Use of temporary concrete barriers will be required.

The final embankment foreslopes should be reinstated as presented in Section 5.1.12 Embankment Foreslopes.

### 5.1.3 Foundation Design

The culvert will be located approximately at the same elevation and location as the existing culvert. As the proposed culvert is not expected to be heavily loaded, a shallow foundation is considered suitable for this site. As the cross sectional area of the box culvert structure will be larger than existing structure, the overall effect on the culvert foundation soils will be a small decrease in stress at the base of the culvert.

The geotechnical resistance was estimated for the ultimate limit state (ULS) and serviceability limit state (SLS) for a maximum settlement of 25 mm. The resistance at ULS was calculated by applying load resistance factor of 0.5 according to the Bridge Design Code (CHBDC) CAN/CSA-S6-06 section 6.6.3.6, Table 6.1. The geotechnical resistance was estimated assuming a strip footing consisting of a width equal to foundation base of two cell precast box culverts (7.0 m) and a depth of the culvert base equal to 0 m, which is a temporary worst condition prior to backfill that will be encountered during construction. Settlement of the structure can be considered negligible due to the marginal change in net loading. While ULS is not relevant at final condition due to excessive soil cover SLS is not relevant for temporary condition. Therefore SLS reported here are for final condition.

Table 5.1 Geotechnical resistances and reactions

Footing Size	Ultimate bearing capacity (kPa)	Factored Resistance at ULS (kPa)	Resistance at SLS (kPa)
B = 7.0 m	94	47	47

The width of the sub-excavation should be twice the width of the culvert and where unsuitable or

unstable soils are encountered, the foundation soils must be removed to a firm or hard soils and replaced to the foundation grade. If sub-excavation for frost effects is carried out in the dry (with adequate dewatering controls), the material can be replaced with Granular A material meeting SSP 110S13 specifications and compacted to a minimum of 95 % of standard Proctor maximum dry density in accordance with OPSS 501. If sub-excavation for frost effects is carried out in the wet (water is maintained at or above adjacent groundwater table) All foundation preparation should be completed as required by OPSS 422, as specified in the contract documents and as indicated in Section 5.1.7 Bedding.

#### 5.1.4 Embankment Design

Slope stability analyses were carried out with limit equilibrium methods using Geoslope version 2004 software applying Morgenstern and Price methods. Targeted factor of safety for slope stability analyses was 1.3 for permanent stability analyses. Slope stability analyses were performed under the following slope conditions with an embankment height of up to 4.0 m:

- Stage 1 temporary embankment with minimum 2.5H:1V upper and 1.5H:1V lower granular fill foreslopes over existing eastbound lane,
- Stage 2 temporary embankment with minimum 2H:1V upper and 1.5H:1V lower granular fill foreslopes over reinstated westbound lane,
- Reinstated embankment eastbound lane after culvert replacement with 3H:1V upper and 2H:1V lower granular fill foreslopes,
- Reinstated embankment westbound lane after culvert replacement with 3H:1V upper and 2H:1V lower granular fill foreslopes.

Results indicate that stability will meet or exceed suitable design factors of safety under both short and long term conditions for the evaluated slope configurations and are presented in Table 5.2.

Table 5.2 Summary of stability analyses

Slope Condition	Foreslope Gradient	Drained or Undrained Analyses	Factor of Safety
Stage 1: Temporary embankment over existing eastbound lane, excavation of westbound lane	2.5H : 1V Upper	Drained	1.2
	1.5H : 1V Lower	Undrained	1.4
Stage 2: Temporary embankment over reinstated westbound lane, excavation of eastbound lane	2.0H : 1V Upper	Drained	1.2
	1.5H : 1V Lower	Undrained	1.3
Embankment after culvert replacement with granular foreslopes, eastbound lane	3.0H : 1V Upper	Drained	1.3
	2.0H : 1V Lower	Undrained	1.4
Embankment after culvert replacement with granular foreslopes, westbound lane	3.0H : 1V Upper	Drained	1.3
	2.0H : 1V Lower	Undrained	1.5

This analyses considered the soil parameters as defined in Table 5.3 and a water table at 3.0 m below the top of embankment in reinstated and temporary embankment conditions.

Excavation of temporary side slopes above the water table that do not support traffic should not be steeper than 1H:1V, although, flatter slopes may be required depending on construction methods. Temporary granular slopes above the water table supporting traffic during the construction stages should not be steeper than 2H:1V. Design of temporary slopes below the water table will depend on the dewatering method. Embankment foreslopes should be reinstated as indicated in Section 5.1.12 Embankment Foreslopes.

The trench width must be sufficient to permit proper use of compaction equipment suited for the material to be compacted, to reach the degree of compaction required, and to accommodate within the space available as per OPSS 501, "Construction Specification for Compaction".



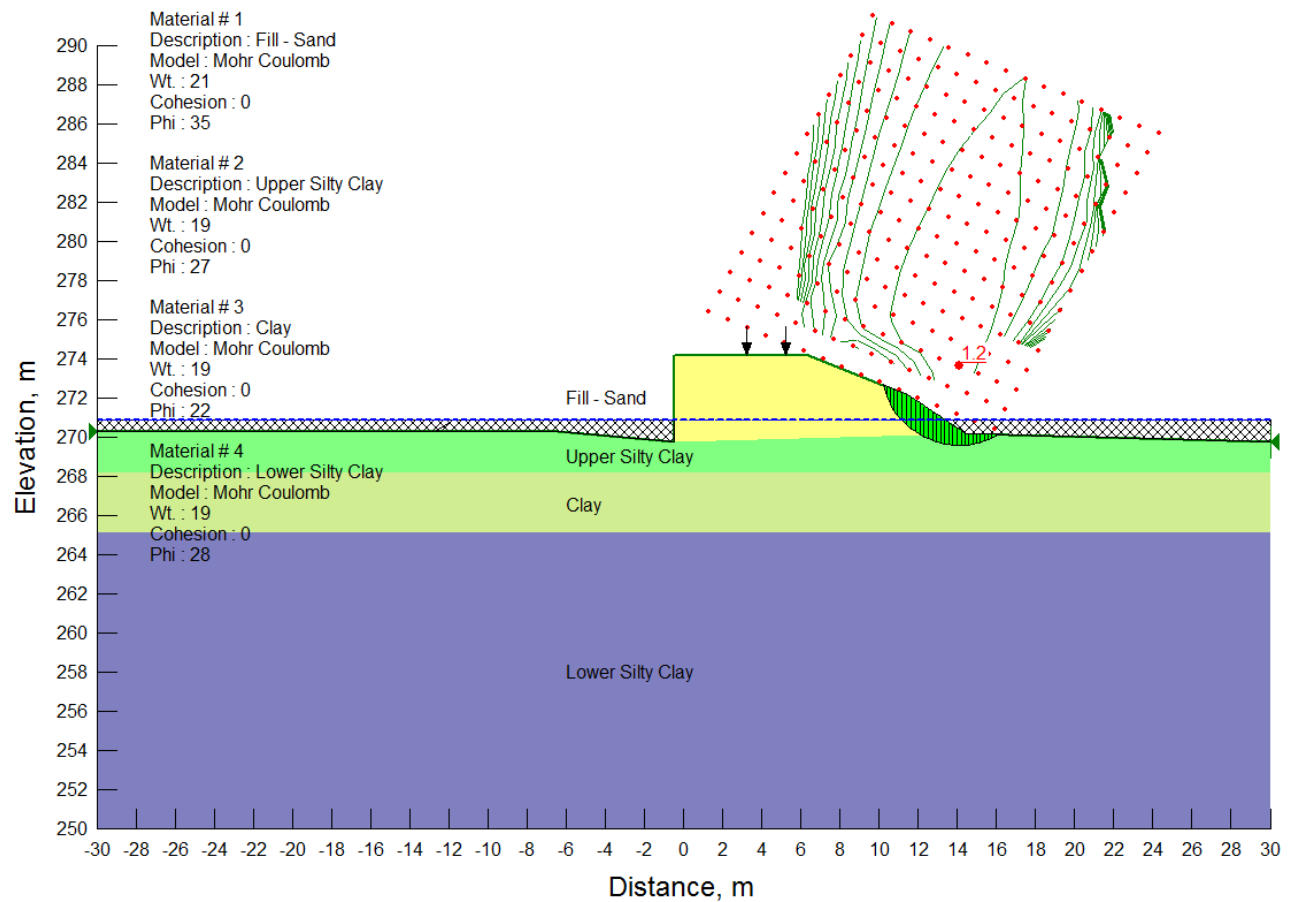


Figure 5.1 Slope stability analysis Stage 1 temporary embankment with minimum 2.5H:1V upper and 1.5H:1V lower granular fill foreslopes over existing eastbound lane under drained condition

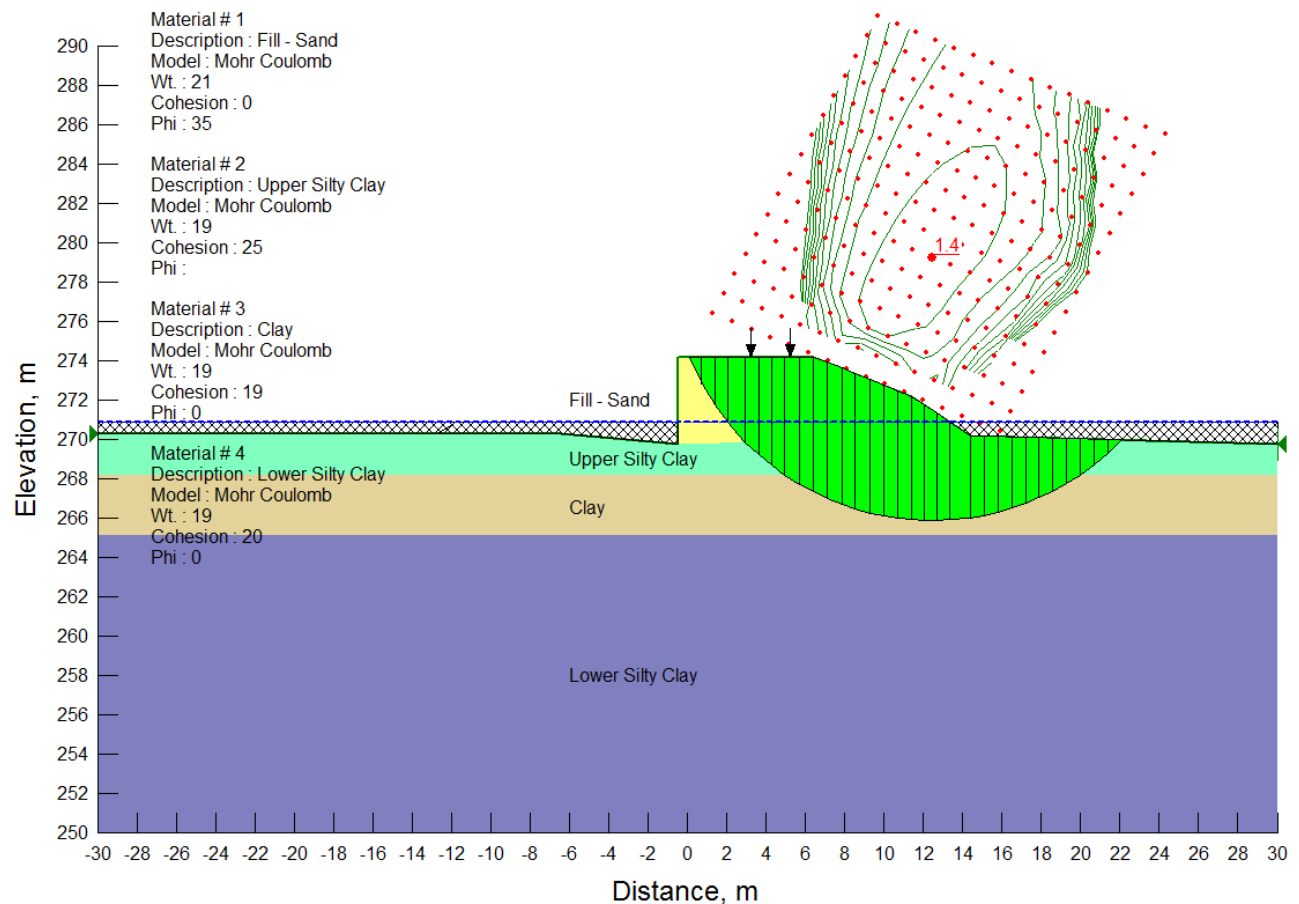


Figure 5.2 Slope stability analysis Stage 1 temporary embankment with minimum 2.5H:1V upper and 1.5H:1V lower granular fill foreslopes over existing eastbound lane under undrained condition

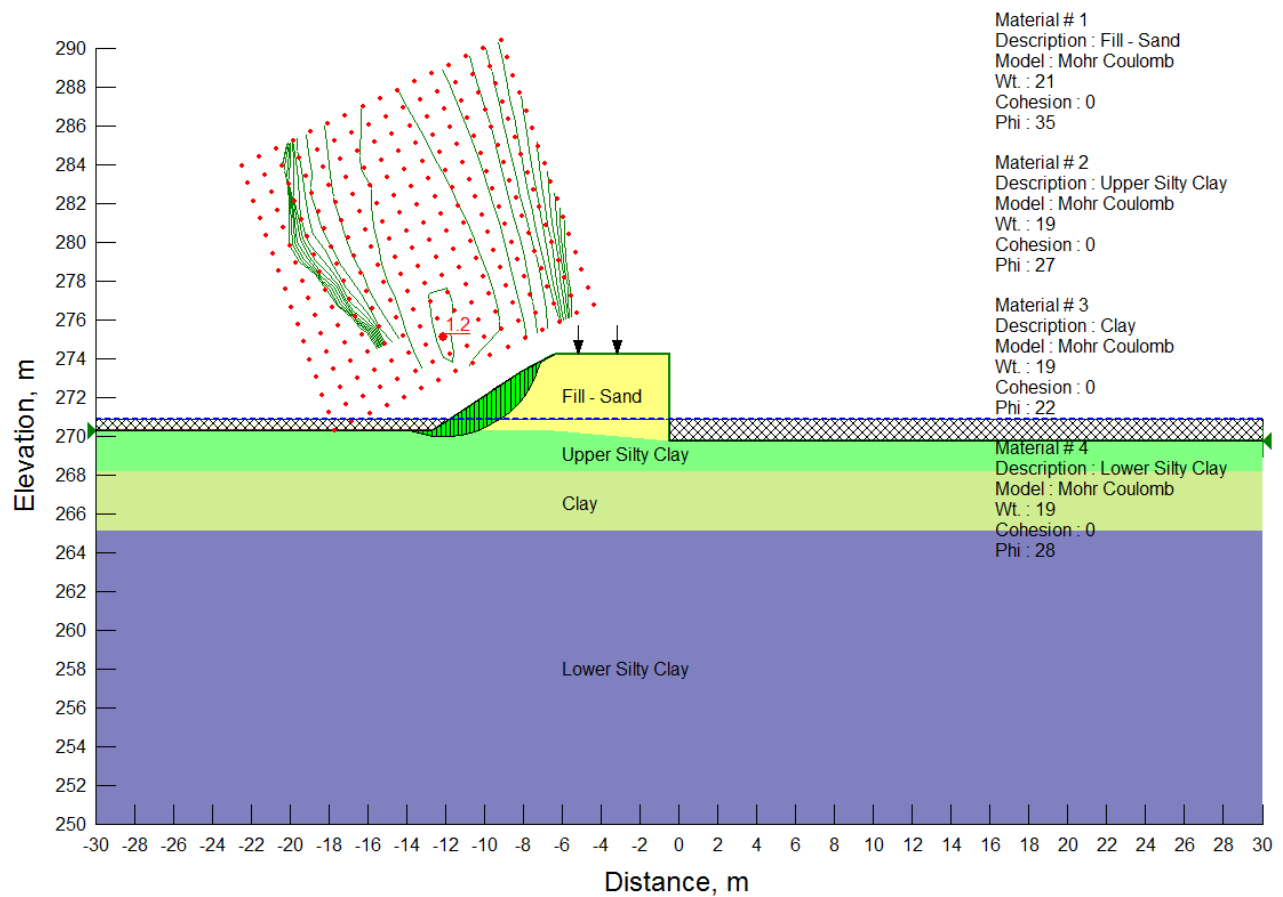


Figure 5.3 Slope stability analysis Stage 2 temporary embankment with minimum 2H:1V upper and 1.5H:1V lower granular fill foreslopes over reinstated westbound lane under drained condition

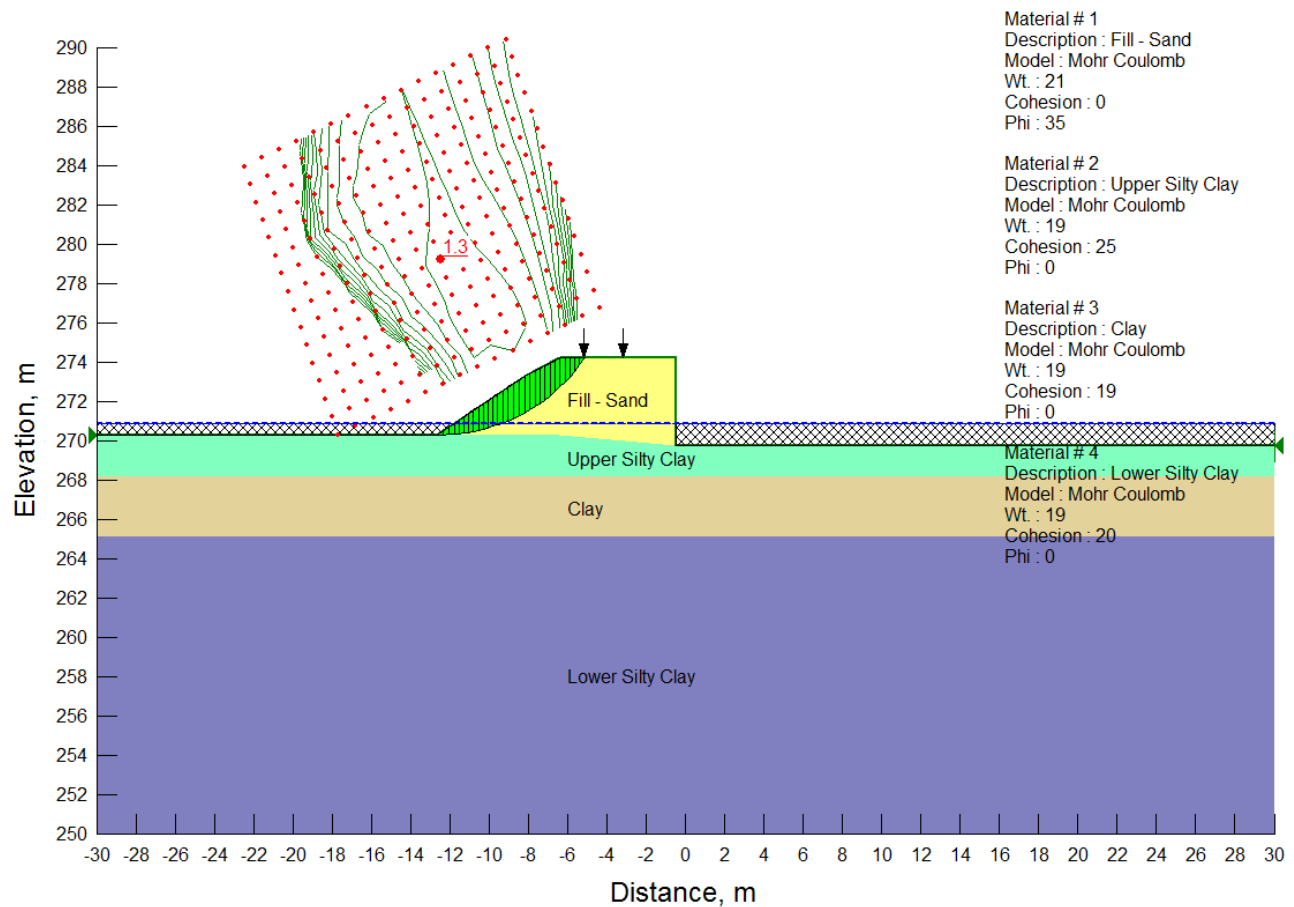


Figure 5.4 Slope stability analysis Stage 2 temporary embankment with minimum 2H:1V upper and 1.5H:1V lower granular fill foreslopes over reinstated westbound lane under undrained condition

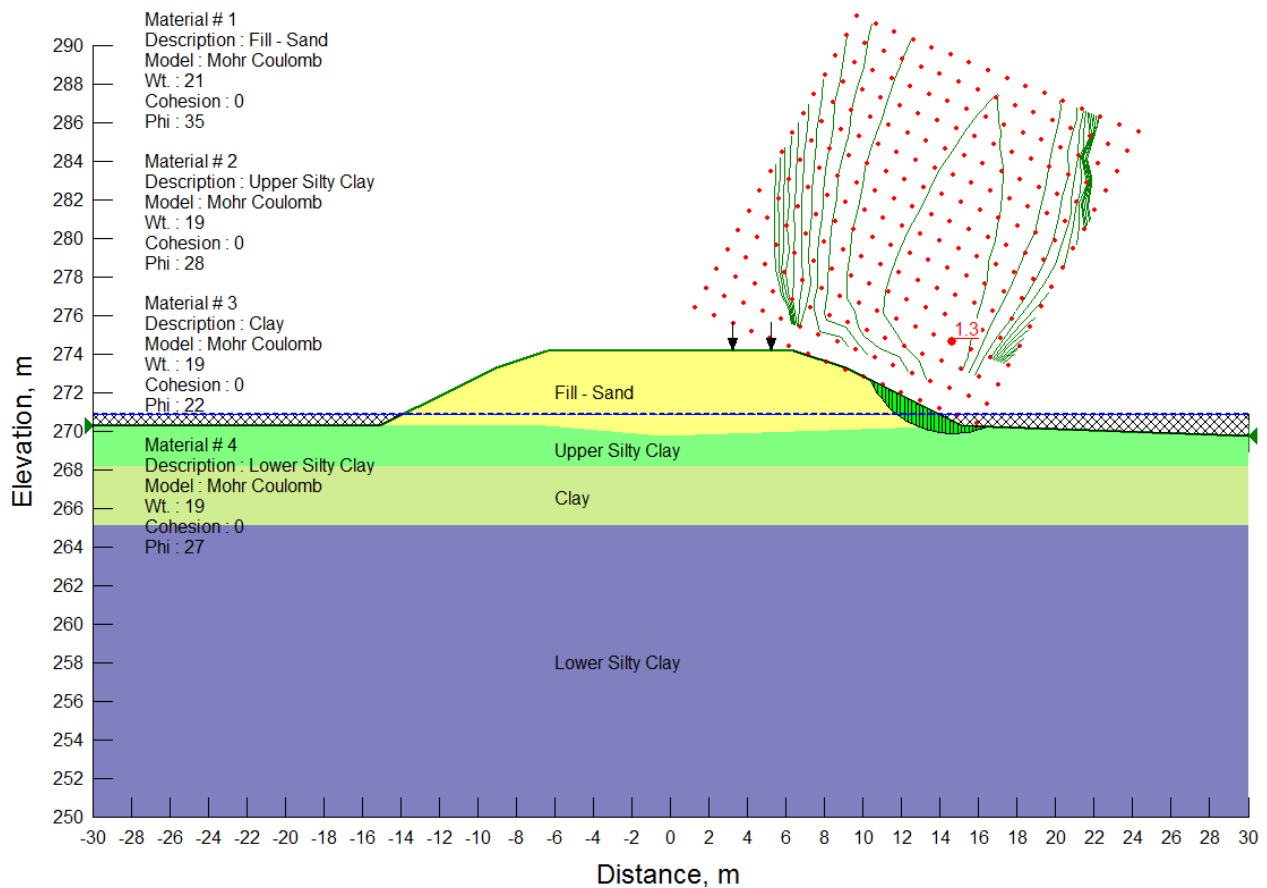


Figure 5.5 Slope stability analysis reinstated embankment eastbound lane after culvert replacement with 3H:1V upper and 2H:1V lower granular fill foreslopes under drained condition

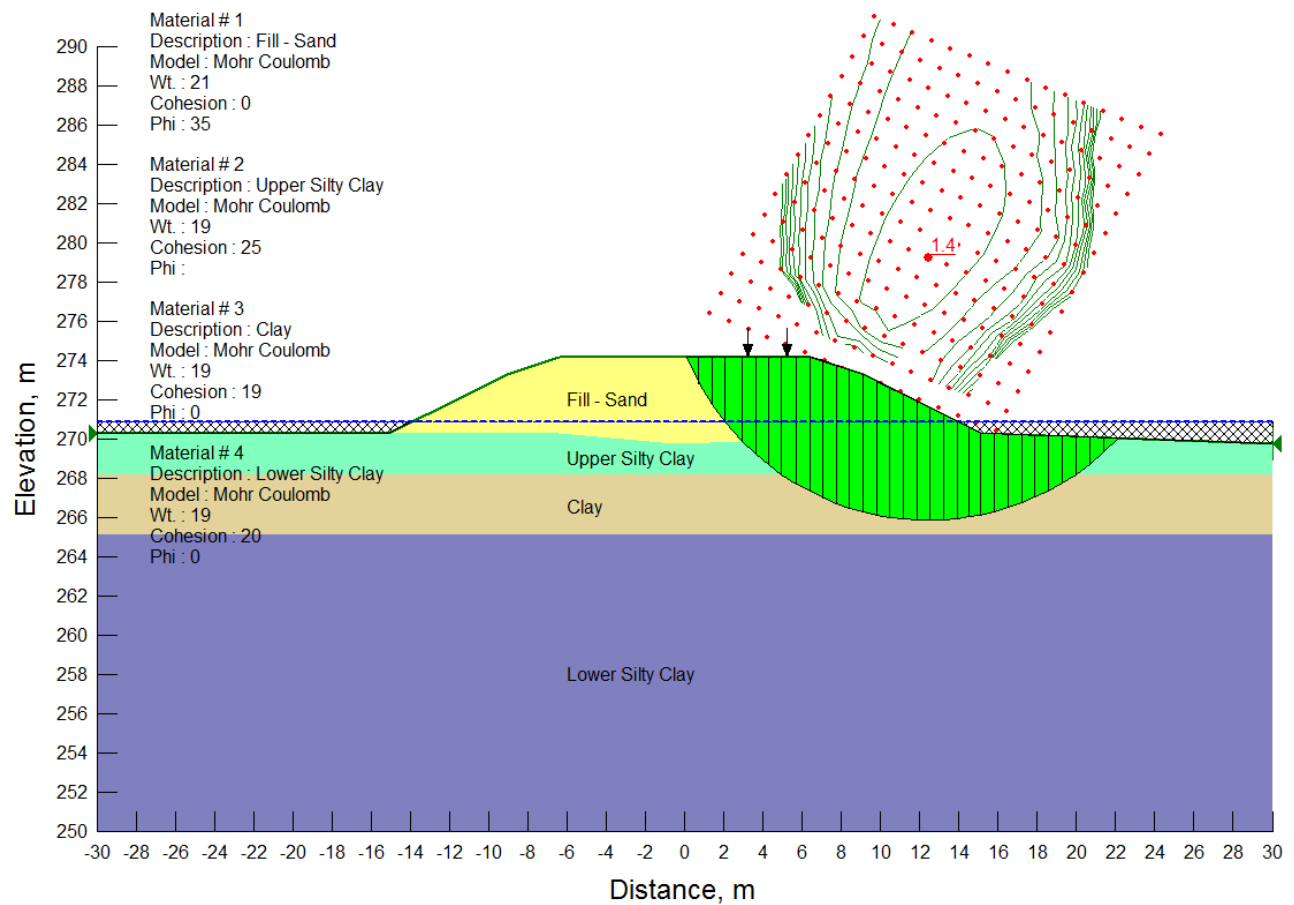


Figure 5.6

Slope stability analysis reinstated embankment eastbound lane after culvert replacement with 3H:1V upper and 2H:1V lower granular fill foreslopes under undrained condition



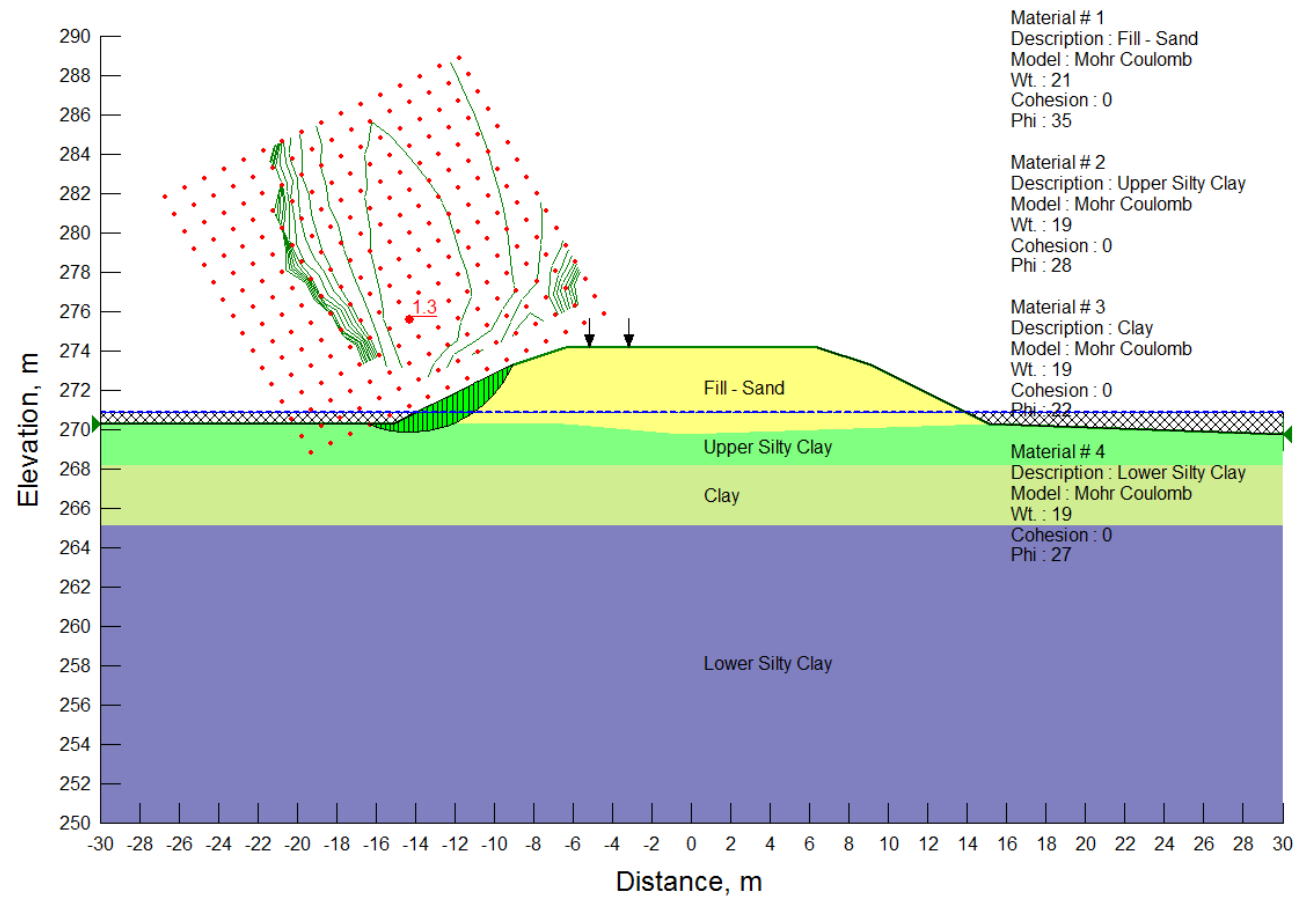


Figure 5.7 Slope stability analysis reinstated embankment westbound lane after culvert replacement with 3H:1V upper and 2H:1V lower granular fill foreslopes under drained condition

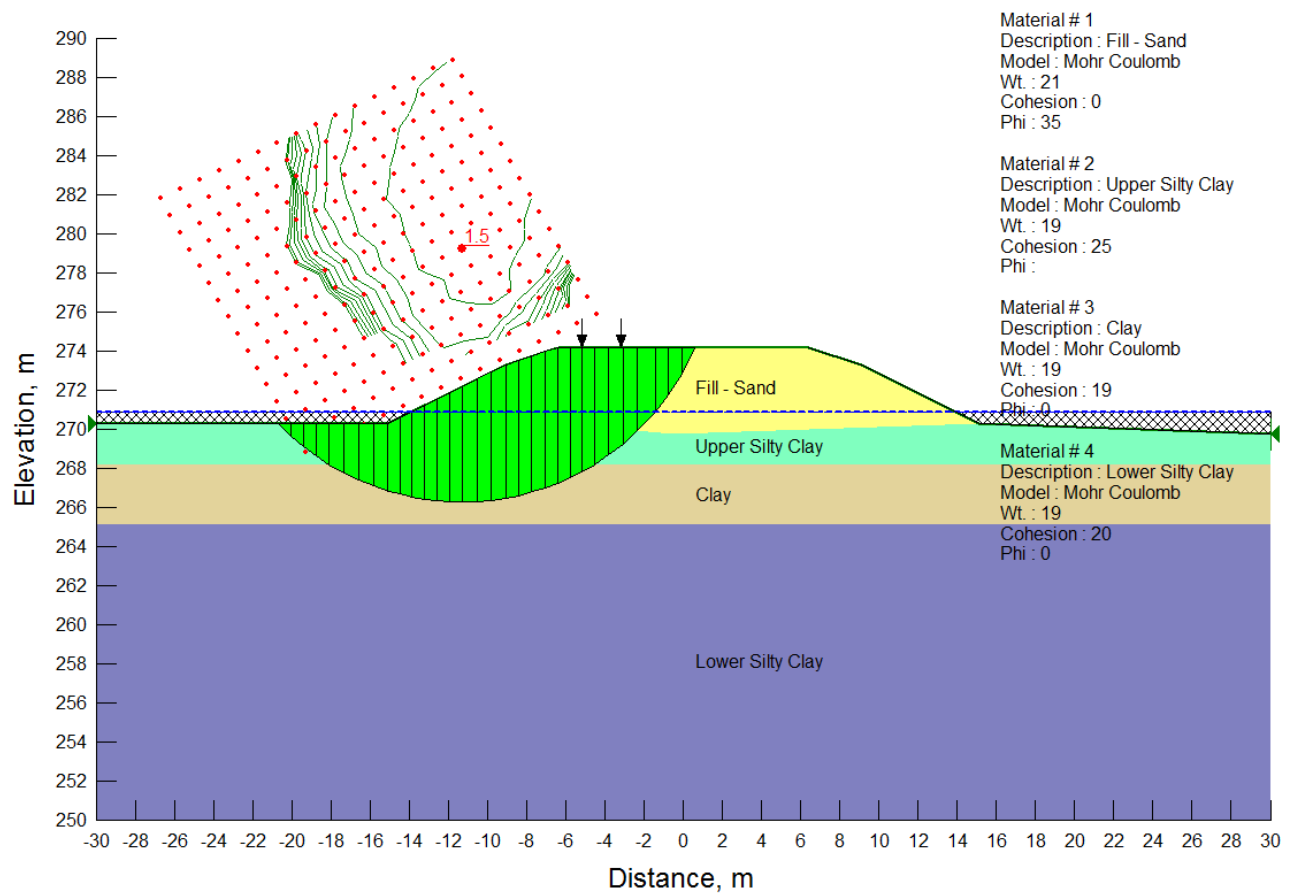


Figure 5.8 Slope stability analysis reinstated embankment westbound lane after culvert replacement with 3H:1V upper and 2H:1V lower granular fill foreslopes under undrained condition

### 5.1.5 Lateral and Sliding Resistances

The analysis of horizontal and vertical effects of earth loads on the culvert can be performed considering soil parameters given in Table 5.3 and assuming linearly variation of stress change with the depth as described in Section 7.8.5.3.2 in Canadian Highway Bridge Design Code. Temporary bracing and shoring may be designed using the typical soil parameters given in Table 5.3, but the designer/contractor should verify the appropriate soil parameters for the designs of specific shoring system.

Concrete toe walls are proposed by the prime consultant to be constructed at the inlet and outlet of the culvert and should be constructed in accordance with OPSD 3120.100.

It is recommended that all excavations be either adequately sloped or securely shored and braced to prevent earth caving and to provide a safe and stable work area. The design should incorporate the effects of hydrostatic pressure, traffic surcharge and retained sloping earth conditions in the shoring design.

Resistance to lateral forces/sliding resistance between the base slab for the replacement of culvert and subgrade should be calculated in accordance with section 6.7.5 of the CHBDC.

The coefficients for lateral earth pressure can be calculated using equations provided in Table 5.4. Where no significant earth movements are expected, the coefficient  $K_0$  should be used.

Table 5.3 Typical soil parameters for earth loads

Soil type	Unit weight (kN/m <sup>3</sup> )	Internal friction angle (Deg)	Interface friction angle, $\delta$ (Deg)	Intact undrained shear strength (kPa)
Rock Fill	22	45	-	-
Granular A	21	35	17	-
Granular B	21	35	17	-
Upper Silty Clay	19	28	16	25
Clay	19	22	15	19
Lower Silty Clay	19	27	16	20

Table 5.4 Lateral Earth Pressure Coefficients

Earth Pressure Coefficient	Equation*
Active Earth Pressure ( $K_a$ )	$\left( \frac{1 - \sin\phi}{1 + \sin\phi} \right)$
Passive Earth Pressure ( $K_p$ )	$\left( \frac{1 + \sin\phi}{1 - \sin\phi} \right)$
At rest ( $K_o$ )	$(1 - \sin\phi)$

\*  $\phi$  is an angle of internal friction

### 5.1.6 Roadway Protection

Roadway protection for this project should be constructed in accordance with the requirements of the Occupational Health and Safety Act of Ontario (OHSA), O.Reg. 213/91. According to O.Reg. 213/91, s.226, the soils in the area of interest classify as Type 3 and Type 4 if located above and below the water table respectively. Type 3 soils generally are stiff to firm and compact to loose or are previously excavated soil, exhibit signs of surface cracking, exhibit signs of seepage, if it is dry, may run easily into a conical pile and have a low degree of internal strength. Type 4 soils generally are soft to very soft and very loose in consistency, very sensitive and upon disturbance are significantly reduced in natural strength, run easily or flow unless it is completely supported before excavation procedure, have almost no internal strength, are wet or muddy and exerts substantial fluid pressure on its supporting system. In accordance with O. Reg. 213/91, s.227 (3), if an excavation contains more than one type of soil, the soil shall be classified with the highest number as described in section 226. These should be assessed and confirmed in the field as construction progresses.

Since roadway protection is required during the culvert replacement, installation of a cantilevered sheet pile system may be considered to ensure the stability of the bank and is a feasible option. Alternatively, the use of soldier piles with lagging installed as the excavation progresses may also be considered. Soldier piles, properly designed, will be more capable of accommodating the presence of cobbles and rock fill expected to be encountered within the embankment fill. The design of sheet pile or soldier pile walls may be performed using the typical soil parameters given in Table 5.3, but the designer/contractor should verify the appropriate soil parameters for the designs. Since the embankment is not to be reduced in height, the potential of encountering rock fill, cobbles and boulders is likely. The contractor should be prepared to handle the presence of rock fill with the selection of adequate driving or vibratory equipment as well as steel thickness.

The construction methodology must be in accordance with OPSS 539 “Construction Specification for Temporary Protection Systems” as well as all Ministry of Transportation, Ministry of Environment, Ministry of Natural Resources and Department of Fisheries and Oceans guidelines, and also the Occupational Health and Safety Act of Ontario. The contractor’s method and equipment must be suitable for the site conditions and materials used.

#### 5.1.7 Bedding

The bedding for the structure should be designed in accordance with the contract documents, Section 7.8.3 of the CHBDC and as specified in OPSS 422 “Construction Specification for Precast Reinforced Concrete Box Culverts and Box Sewers in Open Cut”.

The foundation soils, sensitive clay in particular, will be very susceptible to disturbance and weakening as a result of traffic, standing water and frost. Any foundation soils that could be disturbed shall be protected. The bottom of the excavation on which the culvert or granular pad is to rest shall not be disturbed. The bedding placement should commence immediately after the final removal of material to the foundation level has been completed.

The bedding shall be a minimum of 0.5 m thick and extend to a minimum width (half of the width of culvert) beyond all sides of the culvert. The bedding material should consist of “Granular A” as per Soil Group I in accordance with Table 7.4 of the Canadian Highway Bridge Design Code. The “Granular A” shall be in accordance to SSP 110S13. The “Granular A” should be placed in layers not exceeding 200 mm in thickness, loose measurement, and each layer compacted to a minimum of 95 % of standard Proctor maximum dry density in accordance with OPSS 501. The middle one-third of the culvert width of the top bedding layer, having minimum thickness of 75 mm, shall be loosely placed and uncompacted.

If construction is performed without dewatering bedding material should consist of 19 mm Type I or II clear stone as defined in OPSS 1004.05.02. If fine materials are present beneath the clear stone a non-woven geotextile (OPSS 1860.07.05.01 Class II) with the filtration opening size (FOS) less than 135 µm may be required for separation. No compaction is required for the placement of the clear stone.

As no additional grade raise is anticipated at the culvert location, only marginal changes in net loading above the culvert replacement is anticipated, settlements should then be considered to be occurring under a recompression condition. Therefore, relative settlements along the culvert flow

path can be considered negligible and camber of the bedding is not required.

#### 5.1.8 Sidefill and Overfill

The sidefill and overfill for the structure should be designed in accordance the contract documents, Section 7.8.3 of the CHBDC and as specified in OPSS 422 “Construction Specification for Precast Reinforced Concrete Box Culverts and Box Sewers in Open Cut”.

The material used for culvert sidefill should not contain debris, organic matter, frozen materials, or large stones, must meet SSP110S13 Granular A requirements and be compacted to 95% of standard Proctor maximum dry density in accordance with OPSS 501. Soils shall be deposited uniformly on each side of the structure in order to prevent lateral displacement. The minimum width of the sidefill should be at least half of the culvert width in each side.

Overfill should consist of Granular A and should be compacted to a minimum of 90 or 95 % of Standard Proctor Maximum Dry Density (SPMDD) respectively but not greater than the compaction or equivalent stiffness of soils in the sidefill and bedding zones. All compaction shall be completed in accordance with OPSS 501. Each layer should not exceed 200 mm in thickness, loose measurement. The backfill materials should be separated from the adjacent soil with a non-woven Class II geotextile specified in OPSS 1860.

When a concrete culvert is installed on the undisturbed original ground and fill material is placed around and over the culvert, relative settlements between the fill adjacent to the sides of the culvert and the fill directly over the culvert generates downward frictional forces on the culvert, also effecting a load transfer. This vertical load on the culvert can be determined by multiplying the weight of earth over the top of the box section by the vertical arching factor,  $\lambda_v$ . Vertical arching factors for Type B1 and B2 box culverts in standard installations can be considered 1.20 and 1.35 respectively as indicated in Section 7.8.4.2.3 of the CHBDC.

$$q = \gamma h b \lambda_v, \text{ where}$$

$q$  = vertical load on the culvert

$\gamma$  = unit weight of soil

$h$  = thickness of soil above the culvert



$b$  = width of the culvert, and

$\lambda_v$  = vertical arching factor

However, due to the marginal change in net loading above and directly adjacent the culvert replacement, settlements should be considered to be occurring under a recompression condition. Therefore, relative settlements between the fill adjacent the sides of the culvert and the fill directly over the culvert can be considered negligible which results in no or little downdrag force.

#### 5.1.9 Channel Diversion and Dewatering

The culvert shall be replaced by diverting the creek through a temporary bypass. It is proposed for the temporary bypass to be one of the existing or installed culvert cells. It is important to ensure that a flood in the bypass does not cause damage to the partly constructed permanent works, to the temporary works or to plant. Floods can occur quickly and can cause significant financial consequences if adequate containment strategies are not present.

If the creek has comparatively a small amount of flow that may depend on the season, it may be feasible for the creek flow to be directed by staging construction. In order to prevent back up of water from upstream and downstream, a dyke made of sand bags has sometimes been used as a hydraulic barrier. However, a sheet pile vertical cut-off wall will provide better control of both surface and groundwater. An adequately designed and properly installed sump and pump system will be sufficient due to low permeable nature of underlying soil to dewater and stabilize the excavation without risk of soil disturbance. It should be noted that depending on the season, depth of excavation and amount of water flow through the creek may vary. The contractor should be prepared to tackle this situation. The contractor should be alerted of the high water table and surface water, for example through a non standard special provision (NSSP).

Where dewatering is performed, all dewatering operations should be completed in accordance with OPSS 517 "Construction Specification for Dewatering of Pipeline, Utility, and Associated Structure Excavation". If construction is to be completed in the dry a continuous dewatering operation must be provided to keep the excavation stable and free of water. The excavation must be monitored daily throughout the duration of excavation until the completion of backfilling to confirm this. The dewatering system must be maintained and the surrounding area monitored for impacts to items such as, but not limited to, settlement and groundwater usage. The control of water from the dewatering operation should be accordance with OPSS 518 "Construction

#### Specification for Control of Water from Dewatering Operations”.

Water shall be disposed of so as not to be injurious to public health or safety, property, the environment, fisheries, or any part of the work completed or under construction. Dewatering operations shall be directed to a sediment control device or natural attenuation area prior to discharge to watercourses. If a natural attenuation area is used, a minimum 15 m setback shall be maintained from the receiving watercourse. When water is discharged to a watercourse, the water discharged shall be done in a manner that does not cause erosion or other damage to adjacent lands.

When required, a permit issued by the Ministry of the Environment (MOE) for taking water from a groundwater source shall be obtained.

#### 5.1.10 Erosion Control

Erosion control is essential at inlet and outlet for the successful performance of a culvert. Generally, rip-rap is used to avoid the erosion at inlet and outlet of the culvert. The rip-rap slows down the flow close to the channel bed and prevents culvert failure by the undermining.

To prevent erosion of the surrounding soils at the inlet, rip-rap Treatment shall be applied accordance with OPSD 810.020 “Rip-Rap Treatment for Ditch Inlets” and OPSS 511 and SP511S01 “Construction Specification for Rip-Rap, Rock Protection, and Granular Sheeting”.

The outlet shall be rip-rapped to prevent erosion of the surrounding soils accordance with OPSD 810.010 “Rip-Rap treatment for Sewer and Culvert Outlets” and OPSS 511 and SP511S01 “Construction Specification for Rip-Rap, Rock Protection, and Granular Sheeting”.

To prevent undermining of the bedding, cutoff walls shall be installed along the entrance and exit end bottom sides of culvert. Cutoff wall should be designed based on velocity of the water flow and the type of soil underneath.

Considering the replacement of Granular A material underneath and in front of the inlet and replacement of cover material with clear stone or granular material, a clay seal should be considered to minimize underflow. A blanket clay seal should be at minimum 300 mm thick and extend 2 m beyond the fill materials. Clay seals should be constructed in accordance with OPSS 422 and have material properties as specified in OPSS 1205. Alternatively, a geosynthetic clay liner or an ethylene propylene diene monomer (EPDM) liner installed to manufacturer’s specifications may also be

suitable.

The temporary erosion and sedimentation measures during the construction of culvert shall be controlled as described in OPSS 805 "Construction Specification for Temporary Erosion and Sedimentation Control Measures".

#### 5.1.11 Frost Protection

In accordance with OPSD 3090.100 "Foundation Frost Depths for Northern Ontario", the frost penetration at this location is approximately 2.5 m. The frost susceptible soils shall not be used adjacent to the culvert wall within the depth of frost penetration from the road surface. The soils present under the culvert are frost susceptible (capable of forming thick ice lenses with the associated pressures and heave).

During winter season, ice may form inside the culvert and a low flow rate may assist the ice formation. It is expected that ice may extend to the culvert invert and frost could therefore extend into the soils below the culverts, possibly as deep as 2.5 m. The frost heave may generate additional stresses on the culvert foundation and walls.

Three design approaches are commonly applied; designing the culvert with enough strength and rigidity to tolerate these pressures (recognizing that the maximum differential pressures and movements as a result of frost lensing cannot be accurately quantified); removing the frost susceptible soils within the frost zone; or providing adequate insulation to reduce frost penetration. As the frost penetration is extended below the invert level of the culvert, the frost protection should be in accordance with OPSD 803.010 "Backfill and Cover for Concrete Culverts, Frost Penetration Line below Top of Culvert".

If sub-excavation for frost effects is carried out in the dry (with adequate dewatering controls), the material can be replaced with Granular B Type 1 material compacted to 95% of standard proctor maximum dry density. If the excavation is in the wet (water is maintained at or above adjacent groundwater table) then the material should be rockfill or clear stone surrounded by geotextile, without the need for compaction. Depending on the structural design of the culvert, partial sub-excavation (less than 2.5 m) may also be considered to reduce differential stresses associated with frost; however the exact pressures and movements cannot be accurately quantified.

Acceptable insulation to prevent frost penetration would be 150 mm Dow Styrofoam

Highload 40 Insulation or an equivalent material with a compressive strength of approximately 275 kPa or greater. For a region that has a freezing index greater than 3000 Fahrenheit Degree-Days it is recommended that the insulation be placed beneath the structure and extend 2.44 m from the concrete face of the buried structure.

#### 5.1.12 Embankment Foreslopes

Existing culvert foreslopes are approximately 2.5H:1V to as steep as 1H:1V on the west and east embankment respectively. The foreslopes should be reinstated with a slope not steeper than 2H:1V if being constructed with granular materials. The foreslopes should be reinstated with a slope not steeper than 1.5H: 1V if being constructed with rock fill.

#### 5.1.13 Construction Concerns

The main construction issues that need to be addressed for this site are removal of cover/embankment materials, staged removal of the existing culvert, provisions required for temporary roadway protection, diversion of the channel, excavation below the water table, erosion at inlet and outlet culvert and undermining of culvert bedding, frost/heave in silty soil below culvert and reinstatement of the embankment fill. These items are important for the successful installation of the new culvert. Particular attention should be paid to maintain the integrity of the existing culvert during the staged method of construction as well as the ability of the chosen roadway protection to accommodate the presence of cobbles within the embankment fill.

A Quality Verification Engineer shall be required to inspect the condition of the foundation and surrounding soils before installation of bedding and other backfills and ensure the width of trench and trench slope walls are suitable, and ensure compliance with materials placed and compaction methods.

## 6. CLOSURE

Based on the information collected from field investigation and parameters interpreted from laboratory test results, groundwater monitoring data and information provided by the client, culvert replacement options considered were replacement with precast concrete culvert with the use of roadway protection in the dry as well as in the wet. Table 6.1 below summarizes the advantages and disadvantages of construction in the dry versus construction in the wet. Table 6.2 below summarizes the advantages and disadvantages of the use of sheet pile roadway protection versus soldier pile roadway protection.

Table 6.1 Advantages and disadvantages comparison of construction in the dry versus in the wet

Replacement Option	Advantages	Disadvantages
Precast Concrete Culvert installed with Roadway Protection in the Dry	<ul style="list-style-type: none"> <li>• Allows for inspection of subgrade</li> <li>• Allows for careful preparation of steam bed</li> <li>• Prevention of migration of fines between culvert sections during installation</li> <li>• Allows for proper sealing of culvert sections</li> <li>• Ease of erosion control</li> </ul>	<ul style="list-style-type: none"> <li>• Additional construction cost</li> <li>• Potential of piping of materials if granular materials encountered and inadequate dewatering design used</li> <li>• Specialized construction and design required</li> </ul>
Precast Concrete Culvert installed with Roadway Protection in the Wet	<ul style="list-style-type: none"> <li>• Ease of construction</li> </ul>	<ul style="list-style-type: none"> <li>• Unconfirmed subgrade</li> <li>• Increase in erosion and sedimentation due to flowing water through construction site</li> </ul>

Table 6.2 Advantages and disadvantages comparison of sheet pile versus soldier pile roadway protection

Roadway Protection Option	Advantages	Disadvantages
Sheet Pile	<ul style="list-style-type: none"><li>• Relatively non permeable</li><li>• Increased erosion control</li></ul>	<ul style="list-style-type: none"><li>• Lightweight material may not accommodate presence of cobbles</li><li>• Higher installation cost</li><li>• Specialized construction and design required</li></ul>
Soldier Pile	<ul style="list-style-type: none"><li>• Heavier gauge materials may be better able to accommodate presence of cobbles</li><li>• Lower cost</li></ul>	<ul style="list-style-type: none"><li>• Permeable</li><li>• Potential for erosion of retained materials</li><li>• longer installation time</li></ul>

## 7. REFERENCES

*Canadian Highway Bridge Design Code* (2006), CAN/CSA-S6-06, A National Standard of Canada, Canadian standards Association.

Municipal and Provincial Common, Volume 1 - General & Construction Specifications, "*Ontario Provincial Standard for Roads & Public Works*" Spec No. OPSS 422, 501, 510, 511, 517, 518, 539, 805, 902.

Municipal and Provincial Common, Volume 3 - Drawings for Roads, Barriers, Drainage, Sanitary Sewers, Watermains and Structures, "*Ontario Provincial Standard for Roads & Public Works*" Spec No. OPSD 203.040, 803.010, 810.010, 810.020, 3090.100.

Municipal and Provincial Common, Volume 2 - Material Specifications, "*Ontario Provincial Standard for Roads & Public Works*" Spec No. OPSS 1010, 1860.

Special Provisions, Ontario Provincial Standards, SP110S13.

The Surveys and Design Office, Highway Engineering Division, Ministry of Transportation, 1990, Pavement Design and Rehabilitation Manual.



## 8. LIMITATIONS OF REPORT

A description of limitations which are inherent in carrying out site investigation studies is given in Appendix 'A', and this forms an integral part of this report.

For DST CONSULTING ENGINEERS INC.

Prepared by:



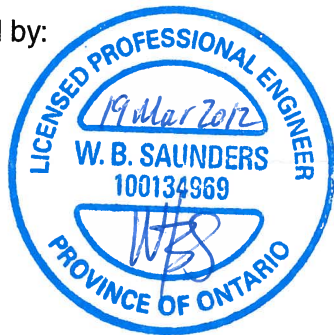
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Project Manager

# **APPENDIX 'A'**

## **LIMITATIONS OF REPORT**

# **LIMITATIONS OF REPORT**

## **GEOTECHNICAL STUDIES**

The data, conclusions and recommendations which are presented in this report, and the quality thereof, are based on a scope of work authorized by the Client. Note that no scope of work, no matter how exhaustive, can identify all conditions below ground. Subsurface and groundwater conditions between and beyond the testholes may differ from those encountered at the specific locations tested, and conditions may become apparent during construction which were not detected and could not be anticipated at the time of the site investigation. Conditions can also change with time. It is recommended practice that a Quality Verification Engineer be retained during construction to confirm that the subsurface conditions throughout the site do not deviate materially from those encountered in the testholes. The benchmark and elevations used in this report are primarily to establish relative elevation differences between the testhole locations and should not be used for other purposes, such as grading, excavation, planning, development, etc.

The design recommendations given in this report are applicable only to the project described in the text and then only if constructed substantially in accordance with details stated in this report. Since all details of the design may not be known, we recommend that we be retained during the final stage to verify that the design is consistent with our recommendations, and that assumptions made in our analysis are valid.

Unless otherwise noted, the information contained herein in no way reflects on environmental aspects of either the site or the subsurface conditions.

The comments given in this report on potential construction problems and possible methods are intended only for the guidance of the designer. The number of testholes may not be sufficient to determine all the factors that may affect construction methods and costs, e.g. the thickness of surficial topsoil or fill layers may vary markedly and unpredictably. The contractors bidding on this project or undertaking the construction should, therefore, make their own interpretation of the factual information presented and draw their own conclusion as to how the subsurface conditions may affect their work.

Any results from an analytical laboratory or other subcontractor reported herein have been carried out by others, and DST Consulting Engineers Inc. cannot warranty their accuracy. Similarly, DST cannot warranty the accuracy of information supplied by the client.

**APPENDIX 'B'**  
**DESCRIPTIVE TERMS**  
**FOR SOIL CLASSIFICATION**

**Descriptive Terms for soil classification:**

As per the soil classification manual by MTO, the descriptive terms based on percent by mass of the whole sample, are described as per following table

<b>Descriptive Term</b>	<b>Example</b>	<b>Percent by Mass of Sample</b>
And (with two major soil types)	Sand and gravel	40-60
Adjective (silty)	Silty	30-40
With	Silt with fine sand	20-30
Some	Silt, some fine sand	10-20
Trace	Sand, trace of gravel	0-10

## EXPLANATION OF TERMS USED IN REPORT

**N VALUE:** THE STANDARD PENETRATION TEST (SPT) N VALUE IS THE NUMBER OF BLOWS REQUIRED TO CAUSE A STANDARD 51mm O.D. SPLIT BARREL SAMPLER TO PENETRATE 0.3m INTO UNDISTURBED GROUND IN A BOREHOLE WHEN DRIVEN BY A HAMMER WITH A MASS OF 63.5kg, FALLING FREELY A DISTANCE OF 0.76m. FOR PENETRATIONS OF LESS THAN 0.3m N VALUES ARE INDICATED AS THE NUMBER OF BLOWS FOR THE PENETRATION ACHIEVED. AVERAGE N VALUE IS DENOTED THUS  $\bar{N}$ .

**DYNAMIC CONE PENETRATION TEST:** CONTINUOUS PENETRATION OF A CONICAL STEEL POINT (51mm O.D. 60° CONE ANGLE) DRIVEN BY 475 J IMPACT ENERGY ON 'A' SIZE DRILL RODS. THE RESISTANCE TO CONE PENETRATION IS MEASURED AS THE NUMBER OF BLOWS FOR EACH 0.3m ADVANCE OF THE CONICAL POINT INTO THE UNDISTURBED GROUND.

SOILS ARE DESCRIBED BY THEIR COMPOSITION AND CONSISTENCY OR DENSENESS.

**CONSISTENCY:** COHESIVE SOILS ARE DESCRIBED ON THE BASIS OF THEIR UNDRAINED SHEAR STRENGTH ( $c_u$ ) AS FOLLOWS:

$c_u$ (kPa)	0 - 12	12 - 25	25 - 50	50 - 100	100 - 200	> 200
	VERY SOFT	SOFT	FIRM	STIFF	VERY STIFF	HARD

**DENSENESS:** COHESIONLESS SOILS ARE DESCRIBED ON THE BASIS OF DENSENESS AS INDICATED BY SPT N VALUES AS FOLLOWS:

N (BLOWS/0.3m)	0 - 5	5 - 10	10 - 30	30 - 50	> 50
	VERY LOOSE	LOOSE	COMPACT	DENSE	VERY DENSE

ROCKS ARE DESCRIBED BY THEIR COMPOSITION AND STRUCTURAL FEATURES AND / OR STRENGTH.

**RECOVERY:** SUM OF ALL RECOVERED ROCK CORE PIECES FROM A CORING RUN EXPRESSED AS A PERCENT OF THE TOTAL LENGTH OF THE CORING RUN.

**MODIFIED RECOVERY:** SUM OF THOSE INTACT CORE PIECES, 100mm+ IN LENGTH EXPRESSED AS A PERCENT OF THE LENGTH OF THE CORING RUN. THE ROCK QUALITY DESIGNATION (RQD), FOR MODIFIED RECOVERY, IS:

RQD (%)	0 - 25	25 - 50	50 - 75	75 - 90	90 - 100
	VERY POOR	POOR	FAIR	GOOD	EXCELLENT

**JOINTING AND BEDDING:**

SPACING	50mm	50 - 300mm	0.3m - 1m	1m - 3m	> 3m
JOINTING	VERY CLOSE	CLOSE	MOD. CLOSE	WIDE	VERY WIDE
BEDDING	VERY THIN	THIN	MEDIUM	THICK	VERY THICK

## ABBREVIATIONS AND SYMBOLS

### FIELD SAMPLING

S S	SPLIT SPOON	T P	THINWALL PISTON
W S	WASH SAMPLE	O S	OSTERBERG SAMPLE
S T	SLOTTED TUBE SAMPLE	R C	ROCK CORE
B S	BLOCK SAMPLE	P H	T W ADVANCED HYDRAULICALLY
C S	CHUNK SAMPLE	P M	T W ADVANCED MANUALLY
T W	THINWALL OPEN	F S	FOIL SAMPLE

### MECHANICAL PROPERTIES OF SOIL

$m_v$	$\text{kPa}^{-1}$	COEFFICIENT OF VOLUME CHANGE
$C_c$	1	COMPRESSION INDEX
$C_s$	1	SWELLING INDEX
$C_\alpha$	1	RATE OF SECONDARY CONSOLIDATION
$c_v$	$\text{m}^2/\text{s}$	COEFFICIENT OF CONSOLIDATION
H	m	DRAINAGE PATH
$T_v$	1	TIME FACTOR
U	%	DEGREE OF CONSOLIDATION
$\sigma'_{vo}$	kPa	EFFECTIVE OVERBURDEN PRESSURE
$\sigma'_p$	kPa	PRECONSOLIDATION PRESSURE
$\tau_f$	kPa	SHEAR STRENGTH
$c'$	kPa	EFFECTIVE COHESION INTERCEPT
$\phi'$	-°	EFFECTIVE ANGLE OF INTERNAL FRICTION
$c_u$	kPa	APPARENT COHESION INTERCEPT
$\phi_u$	-°	APPARENT ANGLE OF INTERNAL FRICTION
$\tau_R$	kPa	RESIDUAL SHEAR STRENGTH
$\tau_r$	kPa	REMOULDED SHEAR STRENGTH
$S_t$	1	SENSITIVITY = $\frac{c_u}{\tau_r}$

### STRESS AND STRAIN

$u_w$	kPa	PORE WATER PRESSURE
$r_u$	1	PORE PRESSURE RATIO
$\sigma$	kPa	TOTAL NORMAL STRESS
$\sigma'$	kPa	EFFECTIVE NORMAL STRESS
$\tau$	kPa	SHEAR STRESS
$\sigma_1, \sigma_2, \sigma_3$	kPa	PRINCIPAL STRESSES
$\epsilon$	%	LINEAR STRAIN
$\epsilon_1, \epsilon_2, \epsilon_3$	%	PRINCIPAL STRAINS
E	kPa	MODULUS OF LINEAR DEFORMATION
G	kPa	MODULUS OF SHEAR DEFORMATION
$\mu$	1	COEFFICIENT OF FRICTION

### PHYSICAL PROPERTIES OF SOIL

$\rho_s$	$\text{kg}/\text{m}^3$	DENSITY OF SOLID PARTICLES	e	1, %	VOID RATIO	$e_{\min}$	1, %	VOID RATIO IN DENSEST STATE
$\gamma_s$	$\text{KN}/\text{m}^3$	UNIT WEIGHT OF SOLID PARTICLES	n	1, %	POROSITY	$I_D$	1	DENSITY INDEX = $\frac{e_{\max} - e}{e_{\max} - e_{\min}}$
$\rho_w$	$\text{kg}/\text{m}^3$	DENSITY OF WATER	w	1, %	WATER CONTENT	D	mm	GRAIN DIAMETER
$\gamma_w$	$\text{KN}/\text{m}^3$	UNIT WEIGHT OF WATER	$S_r$	%	DEGREE OF SATURATION	$D_n$	mm	n PERCENT - DIAMETER
$\rho$	$\text{kg}/\text{m}^3$	DENSITY OF SOIL	$w_L$	%	LIQUID LIMIT	$C_u$	1	UNIFORMITY COEFFICIENT
$\gamma$	$\text{KN}/\text{m}^3$	UNIT WEIGHT OF SOIL	$w_p$	%	PLASTIC LIMIT	h	m	HYDRAULIC HEAD OR POTENTIAL
$\rho_d$	$\text{kg}/\text{m}^3$	DENSITY OF DRY SOIL	$w_{s.}$	%	SHRINKAGE LIMIT	q	$\text{m}^3/\text{s}$	RATE OF DISCHARGE
$\gamma_d$	$\text{KN}/\text{m}^3$	UNIT WEIGHT OF DRY SOIL	$I_p$	%	PLASTICITY INDEX = $w_L - w_p$	v	m/s	DISCHARGE VELOCITY
$\rho_{\text{sat}}$	$\text{kg}/\text{m}^3$	DENSITY OF SATURATED SOIL	$I_L$	1	LIQUIDITY INDEX = $\frac{w - w_p}{I_p}$	i	1	HYDRAULIC GRADIENT
$\gamma_{\text{sat}}$	$\text{KN}/\text{m}^3$	UNIT WEIGHT OF SATURATED SOIL	$I_C$	1	CONSISTENCY INDEX = $\frac{w_L - w}{I_p}$	k	m/s	HYDRAULIC CONDUCTIVITY
$\rho'$	$\text{kg}/\text{m}^3$	DENSITY OF SUBMERGED SOIL	$e_{\max}$	1, %	VOID RATIO IN LOOSEST STATE	j	$\text{KN}/\text{m}^2$	SEEPAGE FORCE
$\gamma'$	$\text{KN}/\text{m}^3$	UNIT WEIGHT OF SUBMERGED SOIL						

# **APPENDIX 'C'**

## **GENIVAR STAGING DRAWINGS**





**APPENDIX 'D'**  
**NON-STANDARD**  
**SPECIAL PROVISIONS**

## **NOTICE TO CONTRACTOR**

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### Special Provision

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#### **FOUNDATION CONDITIONS**

The Contractor is advised of the following foundation conditions:

##### Deception Creek Culvert (Site # 39E-236)

Cobbles were identified within the fill materials within the advanced borehole locations.

The foundation soils, sensitive soil in particular, will be very susceptible to disturbance and weakening as a result of traffic, standing water and frost. Any foundation soils that could be disturbed should be protected. The bottom of the excavation on which the culvert or granular pad is to rest shall not be disturbed. The bedding placement shall commence immediately after the final removal of material to the foundation level has been completed.

The contractor shall be notified of the high water table and surface water elevation as noted in the Foundation Investigation Report for Deception Creek.

##### Deception Creek Tributary Culvert (Site # 39E-255)

Cobbles were identified within the fill materials within the advanced borehole locations.

The foundation soils, sensitive soil in particular, will be very susceptible to disturbance and weakening as a result of traffic, standing water and frost. Any foundation soils that could be disturbed should be protected. The bottom of the excavation on which the culvert or granular pad is to rest shall not be disturbed. The bedding placement shall commence immediately after the final removal of material to the foundation level has been completed.

The contractor shall be notified of the high water table and surface water elevation as noted in the Foundation Investigation Report for Deception Creek Tributary.

## **DEWATERING STRUCTURE EXCAVATION - Item No.**

---

### **Non-Standard Special Provision**

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#### **902.01 SCOPE**

Section OPSS 902.01 of OPSS 902 is amended by the addition of the following:

As part of the work under this item, the Contractor shall:

- Carry out any additional field investigation the Contractor deems necessary in order to engineer the dewatering systems;
- Design and install dewatering systems to construct the work in the dry;
- Provide temporary bypass for watercourse;
- Carry out works necessary for the dewatering system that may include fish salvage/relocation, sheet piling, tremie concrete seal, sand bagging, etc.;

The Contractor shall provide a continuous dewatering operation to keep the excavation stable and free of water. The excavation must be monitored throughout the duration of excavation until the completion of backfilling. The dewatering system must be maintained and the surrounding area monitored for impacts to items such as, but not limited to, settlement and groundwater usage.

The contractor shall also maintain flow in watercourse through the use of a temporary water bypass system which shall be designed to accommodate the design flow rate. The design flows are provided in the contract drawings.

Fish are resident year round in this water body. Wherever a pump is used for dewatering in an area where there possibly may be fish the pump inlet must be suitably screened (with 30 mm clear stone or equivalent) to prevent fish entrainment.

This item includes all installation, modification, and removal of the dewatering system and temporary water passage system as outlined in *OPERATIONAL CONSTRAINTS: Waterbody/Fisheries Protection During Work in Waterbodies and on Waterbody Banks*. All additional excavation and backfill, roadway protection or other temporary works required to provide the temporary bypass shall be included.

The Contractor must satisfy himself with the local conditions and anticipated water flows, levels and flow velocity to be met with during construction. He shall make his own estimate of the facilities required and difficulties to be encountered including the nature of subsurface materials and conditions.

#### **902.03 DEFINITIONS**

Section OPSS 902.03 of OPSS 902 is amended by the addition of the following definitions and

the deletion of the current definitions of these items, as applicable:

<b>Stamped:</b>	Refers to drawings or details that have been reviewed and stamped “Conforms With Contract Documents”. The stamp shall include the date and signature of the Quality Verification Engineer (QVE).
<b>Quality Verification Engineer (QVE):</b>	An Engineer licensed to practice in the Province of Ontario who has a minimum of five (5) years of experience in the field of design and/or construction of dewatering systems. The Contractor shall retain the QVE to ensure conformance with the contract document.
<b>Dewatering System Design Engineer:</b>	An Engineer licensed to practice in the Province of Ontario who has a minimum of five (5) years of experience in the field of design and/or construction of bridges. In addition, the Dewatering System Design Engineer shall have had responsible experience in the design of at least 5 other dewatering systems. The Contractor shall retain the Dewatering System Design Engineer to ensure conformance with the contract documents and issue certificate(s) of conformance for the design.
<b>Certificate of Conformance</b>	The certificate of conformance shall mean a document issued by the dewatering system design engineer confirming that the specified components of the work are in general conformance with the requirements of the contract documents. Certificate shall be signed and sealed by the Dewatering System Design Engineer.

## **902.04 SUBMISSION AND DESIGN REQUIREMENTS**

Section OPSS 902.04 of OPSS 902 is amended by the addition of the following:

Design of components of the dewatering systems shall be in accordance with CAN/CSA-S6-00 and standard referenced therein.

### **Submission of Shop Drawings**

All shop drawings submissions shall bear the seal and signature of the Dewatering System Design Engineer.

The Contractor shall submit to the Quality Verification Engineer shop drawings for review and stamping.

At least two weeks prior to the commencement of dewatering system construction, the

Contractor shall submit to the Contract Administrator, for information purposes only, four (4) sets of stamped drawings/calculations of the dewatering system.

The Contractor shall, at least three (3) weeks prior to the commencement of the dewatering system installation, submit to the QVE for review, four sets of drawings and calculations indicating:

- the dewatering system design, including design criteria and loading;
- the location, type and dimensions of each dewatering system to be used;
- a schematic showing the configuration of all dewatering systems;
- the material and dimensions of dewatering system components to ensure stability of the design excavation and the dewatering system, and the construction sequence and schedule of each component for which the dewatering system is designed.

The QVE shall review all calculations, construction details, shop drawings and procedures.

All submissions shall bear the seal and signature of the Dewatering System Design Engineer and QVE.

### **Certificates of Conformance**

The Dewatering System Design Engineer shall inspect the installation of each component prior to the executing of the next stage in that dewatering system. After the installation/construction of each component, the Contractor shall submit a Certificate of Conformance to the Contract Administrator, sealed and signed by the Dewatering System Design Engineer. The Certificates of Conformance shall state that the dewatering system is in place, and has been installed in conformance with the stamped shop drawings and the Contract Drawings.

The Contractor will note that several Certificates of Conformance may be required, each to coincide with each dewatering system installation.

## **902.07 CONSTRUCTION**

Section OPSS 902.07 of OPSS 902 is amended by the addition of the following:

All concrete work must be carried out in the dry.

Minimum dimensions for the inside face of the dewatering system shall be sufficient for installation of the new culvert.

### **902.07.08 Certificate of Conformance**

Section OPSS 902.07.08 of OPSS 902 is deleted.

## **902.10 BASIS OF PAYMENT**

Section OPSS 902.10 of OPSS 902 is amended by the addition of the following:

Payment at the contract price for the dewatering systems shall be full compensation for all labour, equipment and materials to carry out the work.



**CLAY SEAL - Item No.**

---

**Special Provision**

---

OPSS 902 shall govern, except as amended below:

**902.01                      SCOPE**

Section 902.01 is amended by the addition of the following:

Under this Tender Item, the Contractor shall supply and install the clay seal at the inlet of the culvert.

Alternatively the Contractor may substitute an Ethylene Propylene Diene Monomer (EPDM) membrane barrier in its place.

The EPDM membrane shall conform to ASTM D412 and the following:

Thickness: 60 mils  
Minimum Tensile Strength: 1300 psi  
Minimum Ultimate Elongation: 300%  
Minimum Tear Resistance: 150 lbs/in

The EPDM membrane shall be installed in accordance with the manufacturer's instructions. The membrane shall be securely connected to the fascia of the bottom slab or apron wall and the concrete toe walls or retaining walls as applicable. This connection shall be impermeable. The membrane shall be laid flat over the backfill material and extend 2.0m beyond the extents of the backfill onto native material. The edges of the membrane shall be keyed into the native material 500mm vertically and horizontally and a protective layer of sand backfill, 300mm thick, shall be placed over top of the membrane prior to the placement of scour protection.

## **3000 MM X 2400 MM PRECAST CONCRETE BOX CULVERT - Item No.**

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### **Special Provision**

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OPSS 422 shall apply except as amended:

#### **422.01 SCOPE**

Under this Tender Item, the Contractor shall fabricate, deliver and install the precast concrete box culvert units and precast concrete cut-off walls as shown on the Contract Documents, including the supply and placement of the rigid insulation, and geotextile at the culvert joints at the following site locations:

- Deception Creek Culvert (Site # 39E-236) is a double 3000 mm x 2400 mm precast concrete box culvert,
- Deception Creek Tributary Culvert (Site # 39E-255) is a double 3000 mm x 2400 mm precast concrete box culvert with waterproofing.

The units shall be fabricated in accordance with OPSS 422 except as otherwise specified herein.

#### **422.03 DEFINITIONS**

Section 422.03 shall be amended by the addition of the following paragraph:

**Quality Verification Engineer:** An engineer who has a minimum of five (5) years experience in the construction and inspection of culverts and associated appurtenances. The Quality Verification Engineer shall be retained by the Contractor to ensure conformance with the contract documents and issue of certificate(s) of conformance.

#### **422.04 SUBMISSION AND DESIGN REQUIREMENTS**

Subsection 422.04.01 and 422.04.02 shall be added as follows:

##### **422.04.01 Submission of Shop Drawings**

The design and shop drawings shall bear the seal and signature of a Professional Engineer who is licensed by the Association of Professional Engineers of Ontario.

##### **422.04.02 Submission of Erection Procedures**

The erection drawings shall bear the seal and signature of a Professional Engineer who is licensed by the Association of Professional Engineers of Ontario.

The Quality Verification Engineer shall affix his seal and signature on the erection procedures verifying that the procedures are consistent with the Contract Documents and sound engineering practices.

The erection procedures shall include at least the following:

1. Lifting points locations

2. Details of all temporary supports

**422.05 MATERIALS**

**422.05.11 Geotextile**

Subsection 422.05.11 shall be amended by the addition of the following:

Geotextile to be non-woven, Class II, with a thickness greater than 1mm and a FOS of 50 to 100 microns and shall be according to OPSS 1860.

Section 422.05 shall be amended by the addition of the following subsections:

**422.05.16 Rigid Insulation**

Rigid Insulation shall be Dow Styrofoam Highload 40 Insulation (minimum compressive strength of 275 kPa) or an equivalent material as per OPSS 1605.

**422.07 CONSTRUCTION**

OPSS 422.07 shall be amended by the addition of the following:

**422.07.01 CCIL Certification**

Subsection 422.07.01 shall be amended by the addition of the following paragraphs:

The precast concrete culvert units shall be fabricated by a manufacturer certified in conformance to the "Prequalification Requirements for Manufacturers of Precast Concrete Drainage Products - May 1998", by the MTO/MEA/OCPA/OPS Prequalification Advisory Committee.

Units are to be designed in accordance with the CHBDC 2006 for highway loads with a minimum of 600 mm, to a maximum of 4000 mm of granular fill and roadbase.

**422.07.09 Installing Box Units**

**422.07.09.01 Box Units**

Subsection 422.07.09.01 shall be amended by the deletion of the first sentence of the sixth paragraph and the addition of the following:

Installation of the box units shall commence at the downstream end and proceed in the upstream direction with the bell ends of the box units facing upgrade

Subsection 422.07.09.01 shall be amended by the addition of the following paragraphs:

The Contractor shall keep a copy of the signed and sealed erection procedures on the site during erection of the members.

The Contractor shall notify the Contract Administrator in writing of the starting date at least 1 week prior to the commencement of field operations and erection work shall not be carried out until the Contract Administrator is on the site.

Precast concrete cut-off walls units shall be installed to the alignment and grade shown on the Contract Documents. The installation tolerance is  $\pm 5$  mm horizontally and vertically.

Precast concrete box culvert units shall be installed to the alignment and grade shown on the Contract Documents. The installation tolerance is  $\pm 5$  mm horizontally and vertically.

## **422.08                      QUALITY ASSURANCE**

Section 422.08 shall be amended by the addition of the following subsection:

### **422.08.01                      Certificate of Conformance**

The Contractor shall submit to the Contract Administrator a certificate of conformance signed and sealed by the Quality Verification Engineer upon completion of each of the following operations and prior to the commencement of each subsequent operation:

- Precast Culvert Fabrication
- Precast Cut-off Fabrication
- Precast Culvert Installation

The certificate shall state that the work has been executed according to the specification and /or stamped working drawings.

## **422.10                      BASIS OF PAYMENT**

Section 422.10 shall be deleted and replaced with the following paragraph:

Payment at the Contract price for the above tender item shall be full compensation for all labour, equipment and material to do the work and includes but not limited to surveying, plastic shims, grouting, geotextile, rigid insulation.

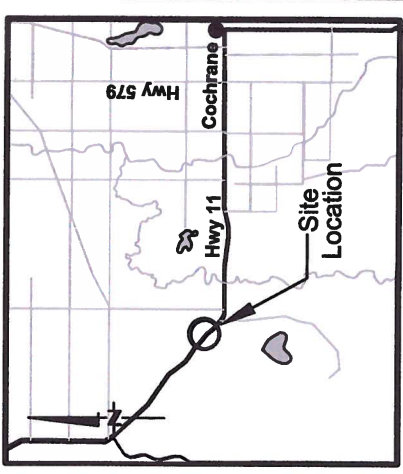
## **D R A W I N G S**

METRIC  
DIMENSIONS ARE IN METRES  
AND/OR MILLIMETRES UNLESS  
OTHERWISE SHOWN. STATIONS  
IN NUMBERS + METERS

CONT No 2012-5119  
GWP No 5149-11-00  
WP No 5112-09-01  
Site No 39E-236  
Geocres No 42H-49

CULVERT REPLACEMENT  
AT DECEPTION CREEK  
Highway 11 - Calder Twp.  
Geotechnical Investigation

SHEET



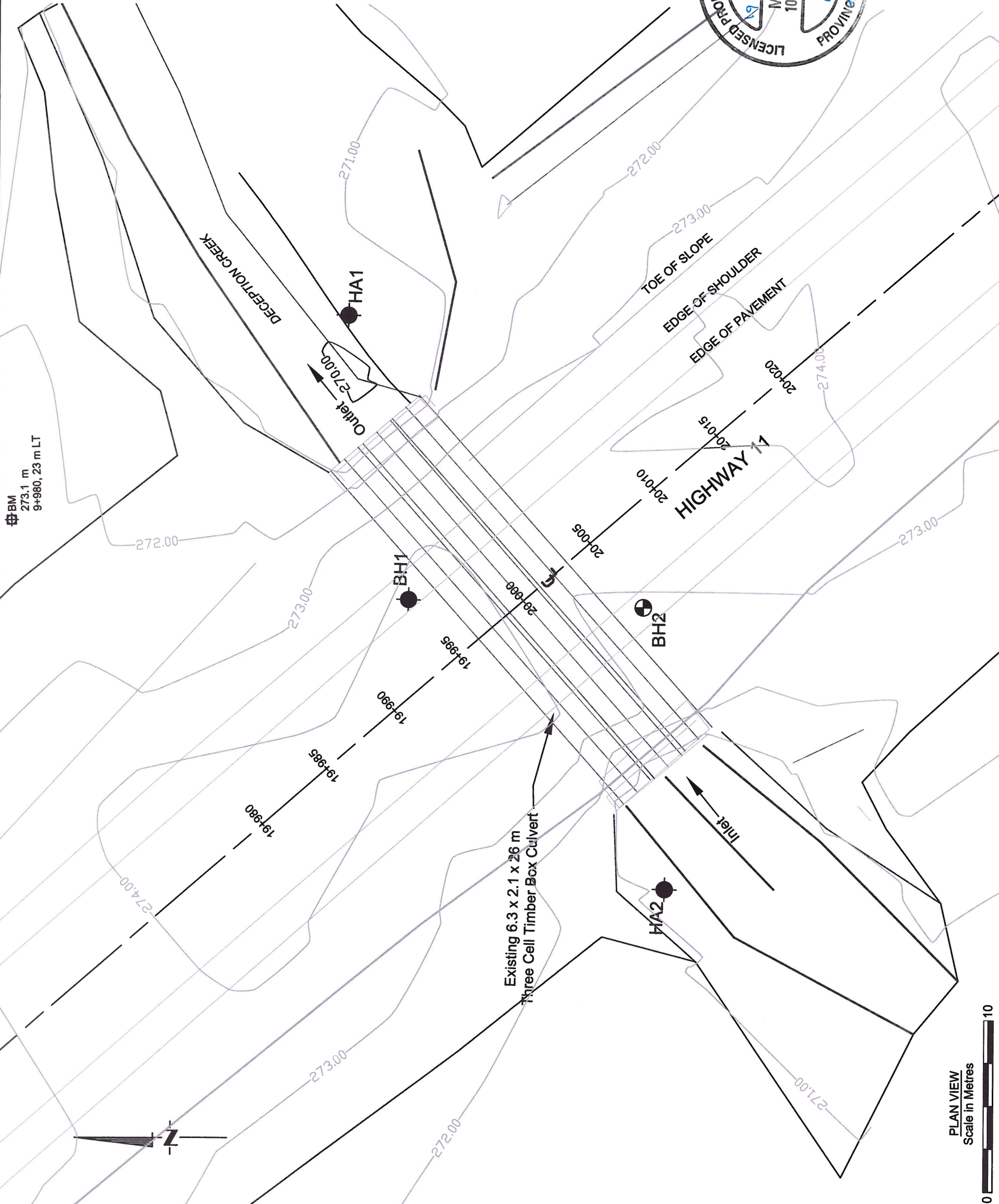
KEY PLAN  
SCALE IN KILOMETRES  
0 20

LEGEND				
◆	Borehole/Hand Auger			
⊕	Borehole with DCPT			
⊕	Dynamic Cone Penetration Test (DCPT)			
●	Rock Probe			
⋈	Blows/0.3m (Std. Pen Test, 475 J/Blow)			
⋈	Water level at time of investigation.			
⊕	Benchmark			
⊕	Fill	⊕	Sand	
⊕	Organics	⊕	Silt	
⊕	Topsoil	⊕	Clay	
⊕	Till	⊕	Sand & Gravel	
⊕	Bedrock	⊕	Boulders	
No.	Elevation	Northing	Easting	Station
BH1	274.240	5435038	47887	19+985
BH2	274.220	5435025	47888	20+005
HA1	270.885	5435040	478703	20+002
HA2	270.910	5435020	478870	19+985



NOTE:  
The boundaries between soil strata have been established only at borehole locations. Between boreholes the boundaries are assumed by interpolation and may not represent actual conditions.

DST Consulting Engineers Inc.  
605 Hewison Street  
Thunder Bay, ON P7B 5V5  
Ph: (807) 822-2929  
Fx: (807) 823-1792  
Email: thunderbay@dstgroup.com

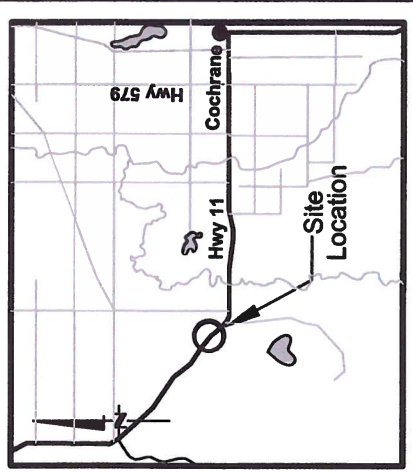
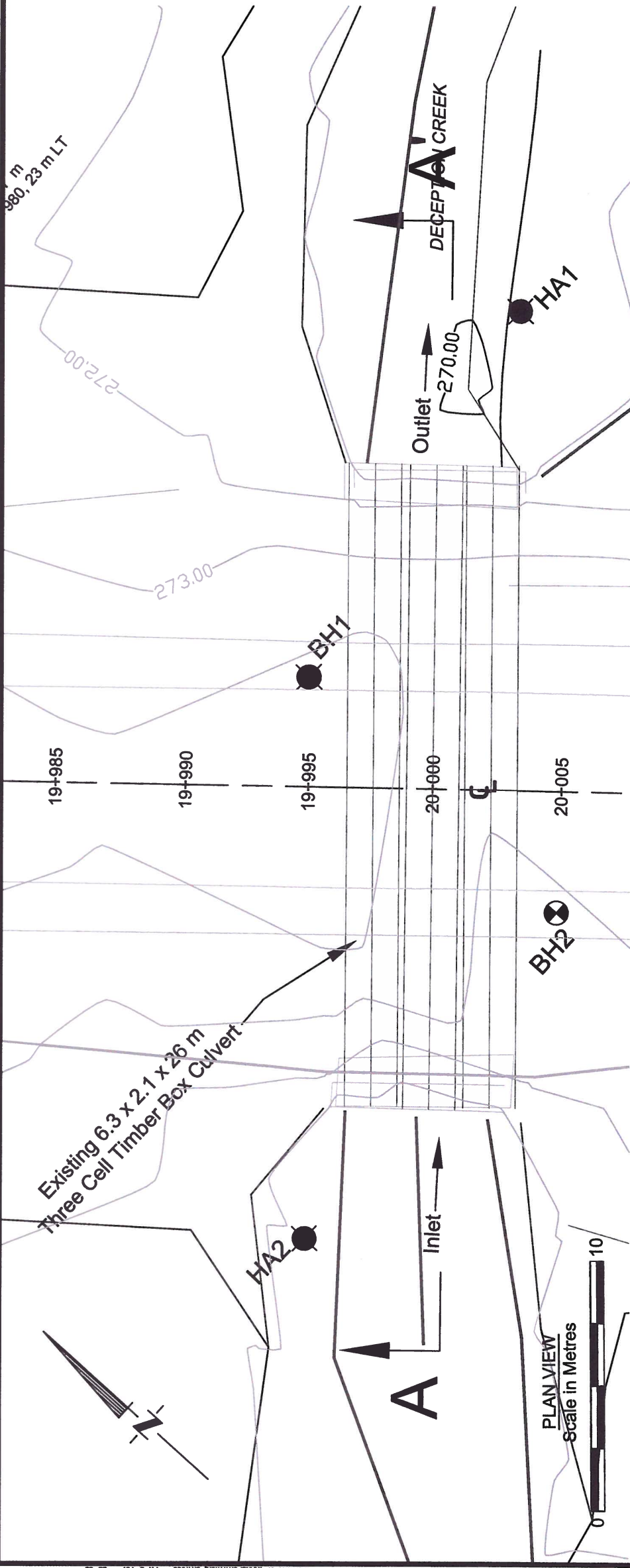


PLAN VIEW  
Scale in Metres  
0 10



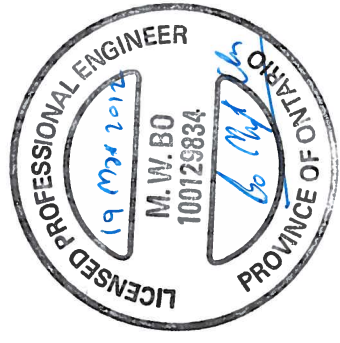
METRIC  
DIMENSIONS ARE IN METRES  
AND FOR ALL DIMENSIONS  
OTHERWISE SHOWN  
IN KILOMETRES + METERS

CONT	No 2012-5119	
GWP	No 5149-11-00	
WP	No 5112-09-01	
Site	No 39E-236	
Geocres No	42H-49	
CULVERT REPLACEMENT AT DECEPTION CREEK Highway 11 - Calder Twp. Geotechnical Investigation		SHEET 10



KEY PLAN  
SCALE IN KILOMETRES  
0 20

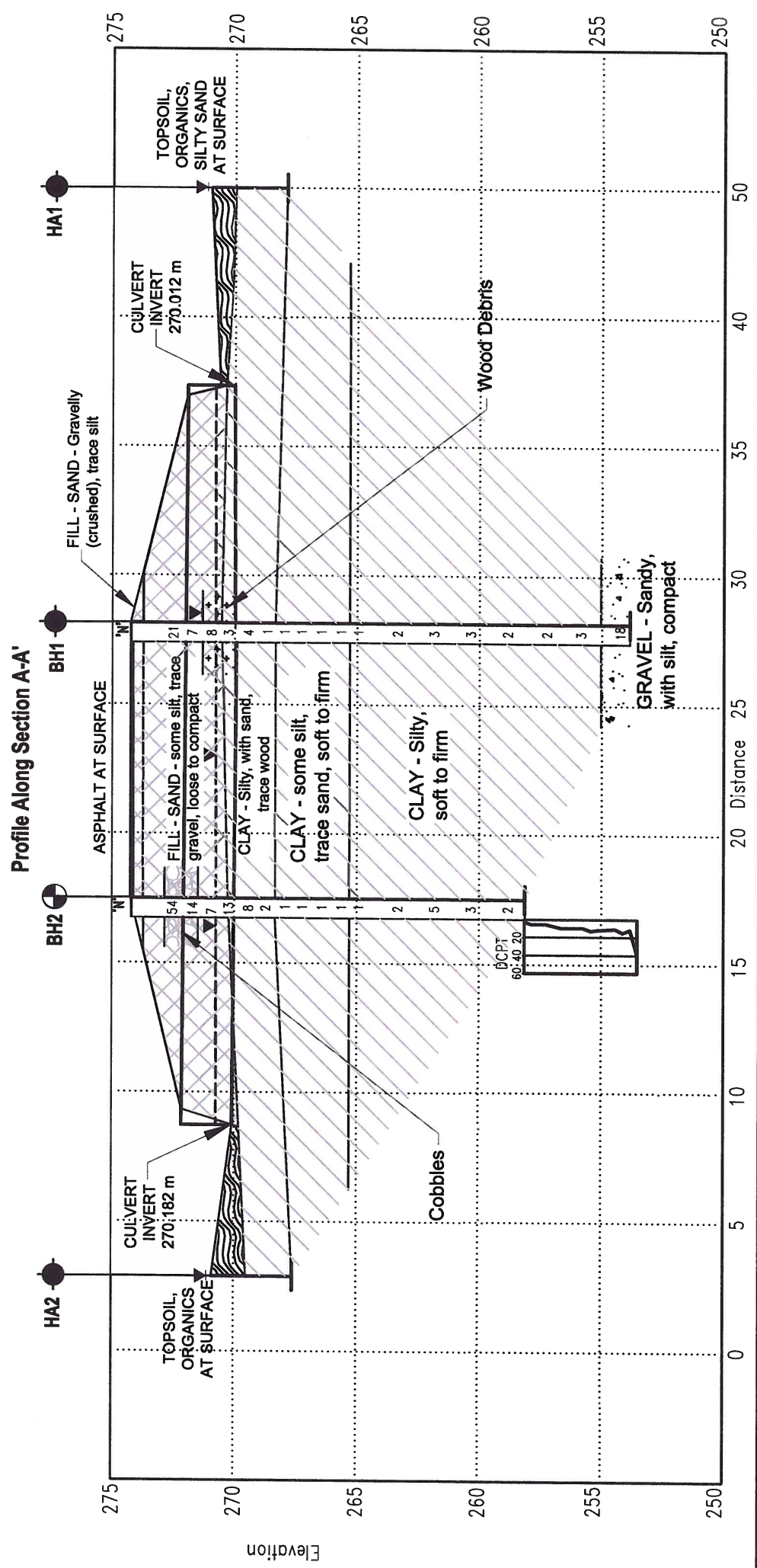
LEGEND					
	Borehole/Hand Auger		Borehole with DCPT		Dynamic Cone Penetration Test (DCPT)
	Rock Probe		Blows/0.3m (Std. Pen Test, 475 J/Blow)		Water level at time of investigation
	Benchmark		Fill		Organics
	Topsoil		Till		Bedrock
	Sand		Silt		Clay
	Sand & Gravel		Boulders		
No.	Elevation	Northing	Easting	Station	Offset
BH1	274.340	5435038	47887	19+885	4.5 LT
BH2	274.220	5435025	47886	20+005	5.0 RT
HA1	270.885	5435040	478763	20+002	20.0 LT
HA2	270.910	5435026	478670	19+885	18.55 RT



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Email: thunderbay@dstgroup.com

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Thunder Bay, ON P7B 5V5  
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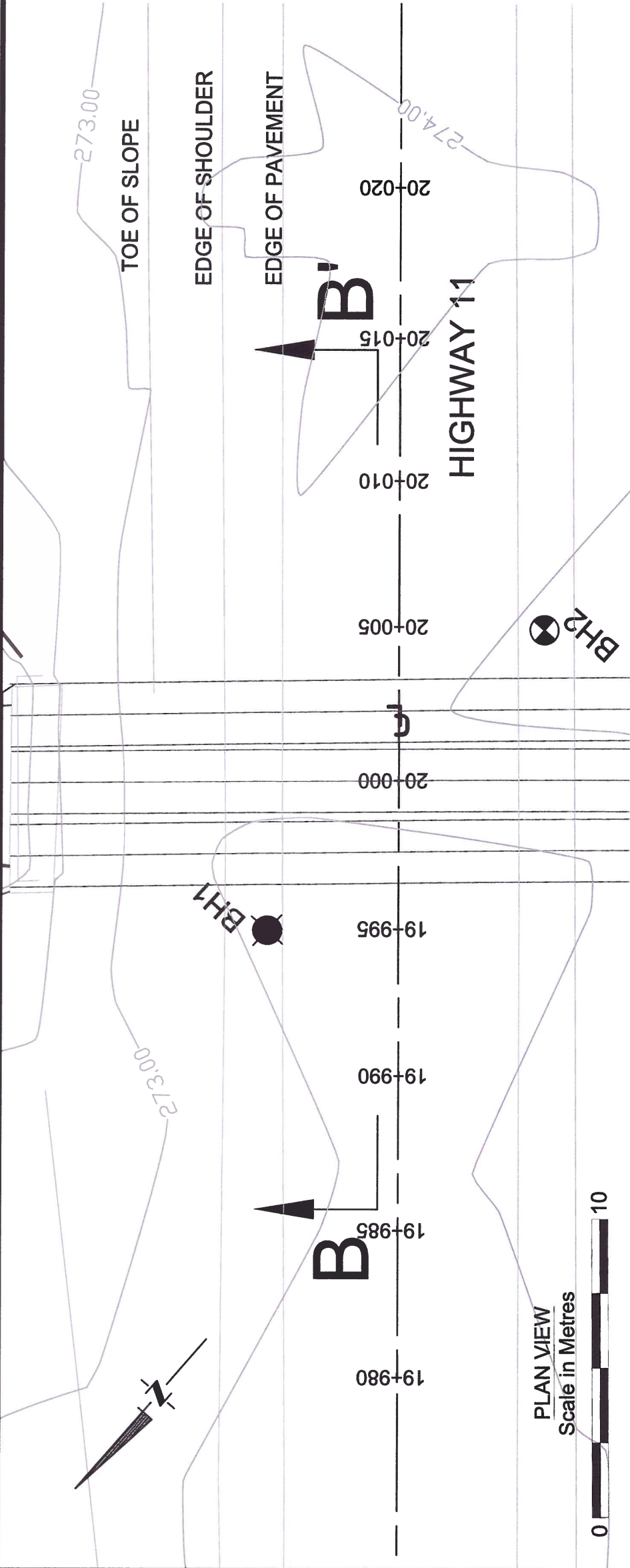
NOTE:  
The boundaries between soil strata have been established only at borehole locations. Between boreholes the boundaries are assumed by interpolation and may not represent actual conditions.





METRIC  
DIMENSIONS ARE IN METRES  
AND/OR MILLIMETRES UNLESS  
OTHERWISE SHOWN. STATIONS  
IN KILOMETRES + METERS

CONT	No 2012-5119	
GWP	No 5149-11-00	
WP	No 5112-09-01	
Site	No 39E-236	
Geocres No	42H-49	
CULVERT REPLACEMENT AT DECEPTION CREEK Highway 11 - Calder Twp. Geotechnical Investigation		SHEET 11

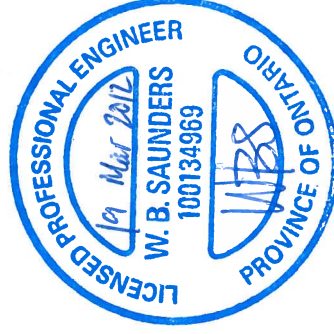
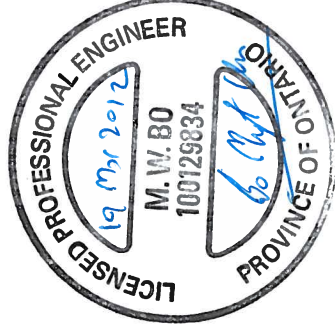
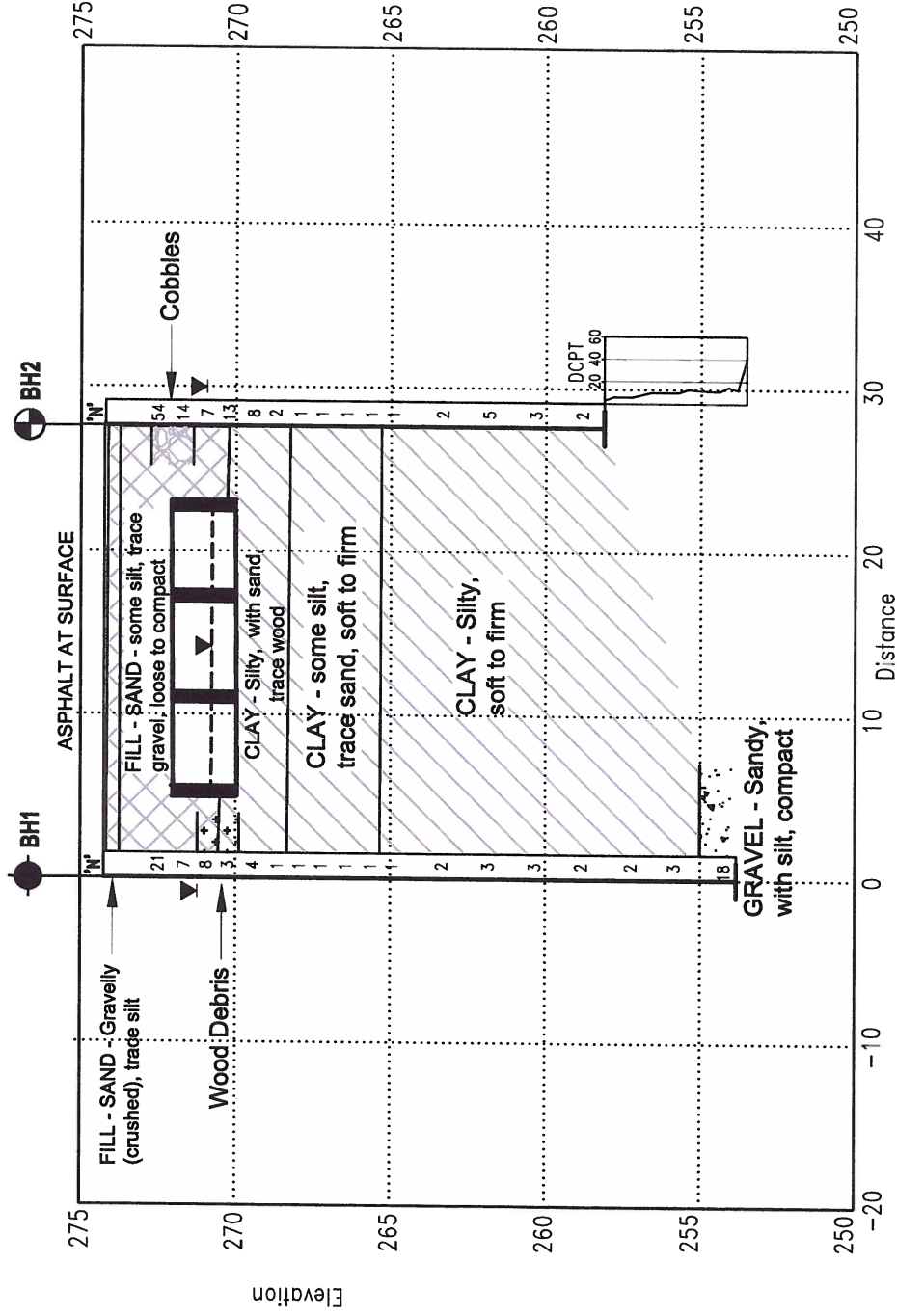


PLAN VIEW

Scale in Metres



Profile Along Section B-B'



NOTE:  
The boundaries between soil strata have been established only at borehole locations. Between boreholes the boundaries are assumed by interpolation and may not represent actual conditions.

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605 Hewitson Street  
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## **E N C L O S U R E S**

# RECORD OF BOREHOLE No BH1

1 OF 1

METRIC

W.P. 5112-09-01 LOCATION STA. 19+995.4, 5 m LT (5435039 m N, 478687 m E) ORIGINATED BY KS/JF  
DIST HWY 11 BOREHOLE TYPE Hollow Stem Auger (80 mm ID) COMPILED BY ML  
DATUM NAD83 UTM Zone 17U DATE 2011 04 01 CHECKED BY WS/BV

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W <sub>P</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							WATER CONTENT (%)	
								20 40 60 80 100	20 40 60 80 100							
274.2	GROUND SURFACE															
274.4	ASPHALT - 80 mm		AS1	AS			274							Water at 271.1 m on completion. Cave at 2.1 m.		
273.7	FILL - SAND - Gravelly (crushed), trace silt, brown		AS2	AS			273									
0.5	FILL - SAND - some silt, trace gravel, brown, loose to compact		SS3	SS	21		272							4 86 (10)		
			SS4	SS	7		271									
270.5	----- - wood debris		SS5	SS	8		270									
3.7	CLAY - Silty, with sand, trace wood and organics, grey, firm to stiff		SS6	SS	3		269							0 31 45 24		
			SS7	SS	4		268									
268.2	CLAY - some silt, grey, firm to stiff		SS8	SS	1		267									
6.0			SS9	SS	1		266									
			SS10	SS	1		265									
265.1	CLAY - Silty, grey, firm		SS11	SS	1		264									
9.1			SS12	SS	1		263									
			SS13	SS	1		262									
			SS14	SS	2		261									
			SS15	SS	3		260									
			SS16	SS	3		259									
			SS17	SS	2		258							0 0 79 21		
			SS18	SS	2		257									
			SS19	SS	3		256									
255.0	GRAVEL - Sandy, with silt, occasional cobbles, grey, compact						255									
19.2							254							40 35 (25)		
253.8	End of Borehole at 20.4		SS20	SS	18											
20.4																

ON MOT GS-TB-012144 - DECEPTION CREEK - HWY 11.GPJ DST\_MIN.GDT 6/3/12

✱<sup>3</sup>, ✱<sup>3</sup>: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

ENCLOSURE 1

# RECORD OF BOREHOLE No BH2

1 OF 1

METRIC

W.P. 5112-09-01 LOCATION STA. 20+005, 5.0 m RT (5435025 m N, 478686 m E) ORIGINATED BY KS/JF  
 DIST HWY 11 BOREHOLE TYPE Hollow Stem Auger (80 mm ID) COMPILED BY ML  
 DATUM NAD83 UTM Zone 17U DATE 2011 04 02 CHECKED BY WS/BV

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT   NATURAL MOISTURE CONTENT   LIQUID LIMIT			UNIT WEIGHT $\gamma$  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)					
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		W <sub>P</sub>	W	W <sub>L</sub>		GR	SA	SI	CL		
								20   40   60   80   100	WATER CONTENT (%)										
274.2	GROUND SURFACE					▽	274												
274.1	ASPHALT - 80 mm		AS1	AS			273												
273.7	FILL - SAND - Gravelly (crushed), trace silt, brown		AS2	AS			272												
0.5	FILL - SAND - some silt, trace gravel, brown, loose to compact		SS3	SS	54		271												
	----- - cobbles -----		SS4	SS	14		270												
			SS5	SS	7		269												
270.5	CLAY - Silty, with sand, grey, soft to stiff		SS6	SS	13		268												
3.7			SS7	SS	8		267												
			SS8	SS	2		266												
268.2	CLAY - some silt, trace sand, grey, soft to firm		SS9	SS	1		265												
6.0			SS10	SS	1		264												
			SS11	SS	1		263												
			SS12	SS	1		262												
265.1	CLAY - Silty, grey, soft to firm		SS13	SS	1		261												
9.1							260												
			SS14	SS	2		259												
			SS15	SS	5														
			SS16	SS	3														
			SS17	SS	2														
258.1																			
16.1	End of Borehole at 16.1 m Start DCPT																		
253.5																			
20.7	End of Dynamic Cone Penetration Test																		

Numbers refer to  
Sensitivity

3% STRAIN AT FAILURE

ENCLOSURE 2

# RECORD OF BOREHOLE No HA1

1 OF 1

METRIC

W.P. 5112-09-01 LOCATION STA. 20+002, 20.0 m LT (5435040 m N, 478703 m E) ORIGINATED BY KS/JF  
 DIST HWY 11 BOREHOLE TYPE Hand Auger COMPILED BY ML  
 DATUM NAD83 UTM Zone 17U DATE 2011 03 27 CHECKED BY WS/BV

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT      NATURAL LIMIT                  MOISTURE CONTENT                  LIQUID 		
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✕<sup>3</sup>, ★<sup>3</sup>: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

ENCLOSURE 3

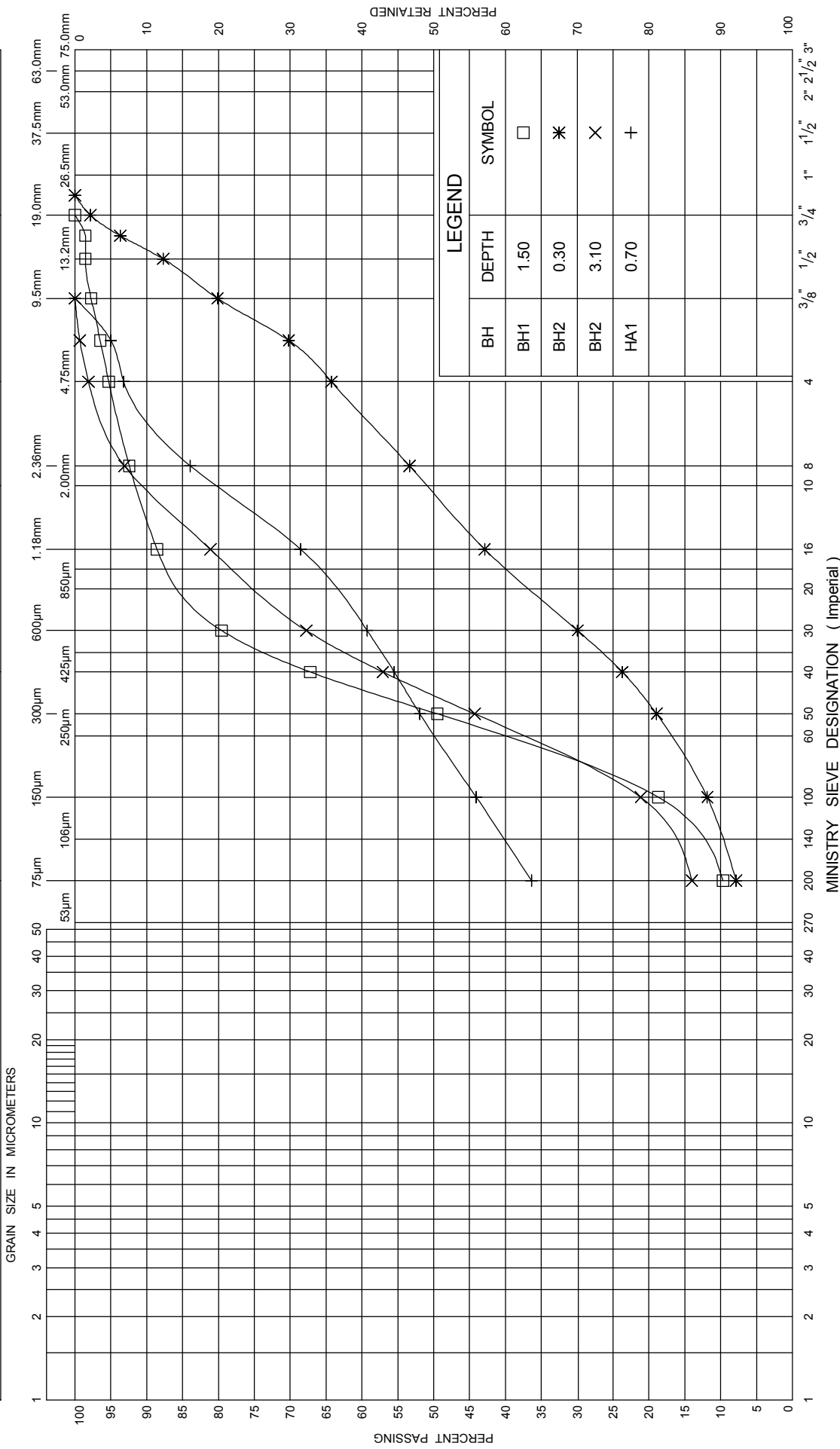
## METRIC

✕<sup>3</sup>, ★<sup>3</sup>: Numbers refer to Sensitivity      ○<sup>3%</sup> STRAIN AT FAILURE

ON\_MOT GS-TB-012144 - DECEPTION CREEK - HWY 11.GPJ DST\_MIN.GDT 6/3/12

UNIFIED SOIL CLASSIFICATION SYSTEM

CLAY & SILT		SAND			GRAVEL		
		Fine		Medium	Coarse	Fine	Coarse



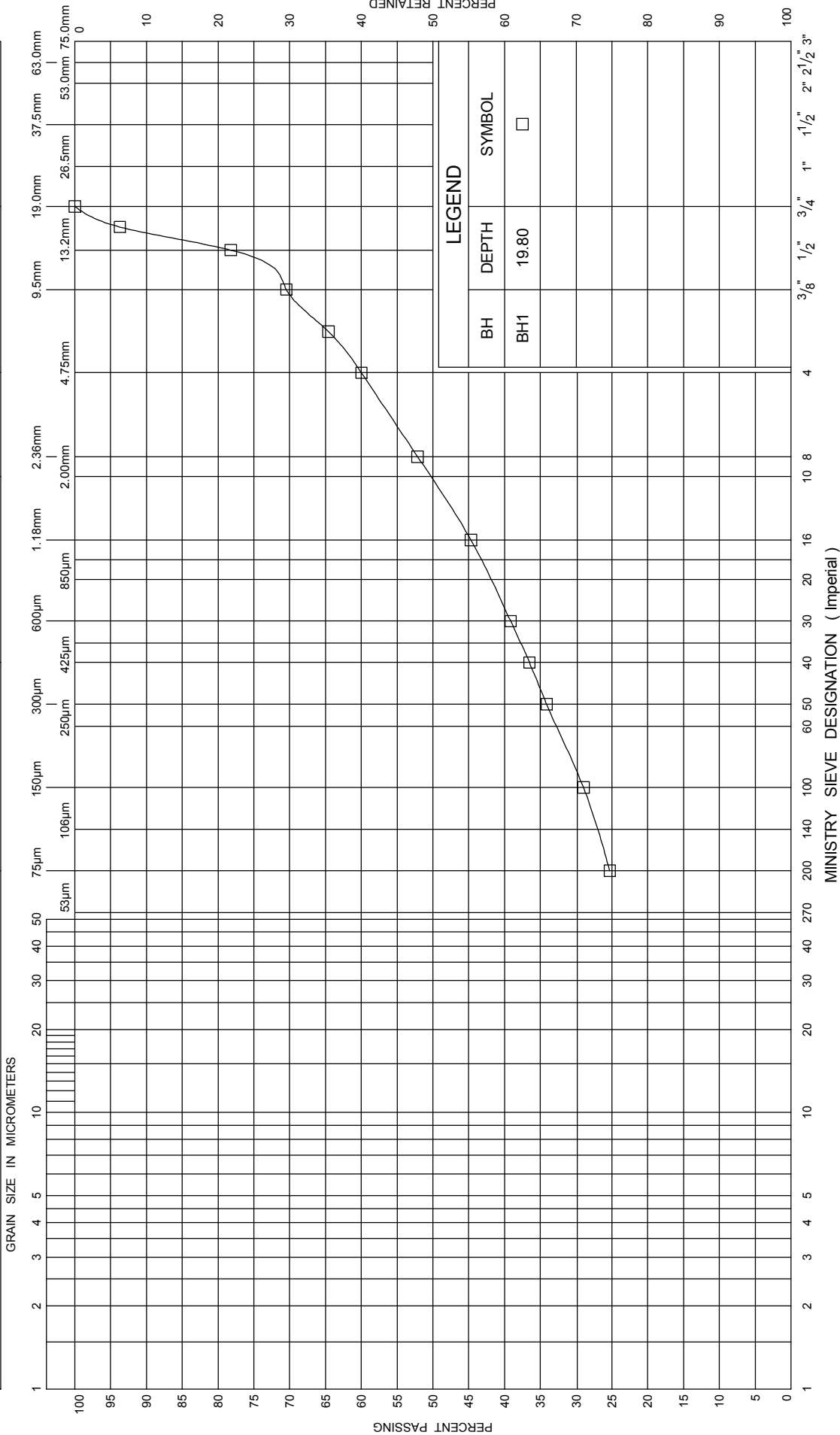
GRAIN SIZE DISTRIBUTION  
SAND

ENCLOSURE 5  
W P 5112-09-01  
HIGHWAY 11



UNIFIED SOIL CLASSIFICATION SYSTEM

CLAY & SILT		SAND			GRAVEL	
		Fine		Medium	Coarse	Coarse



GRAIN SIZE DISTRIBUTION  
GRAVEL

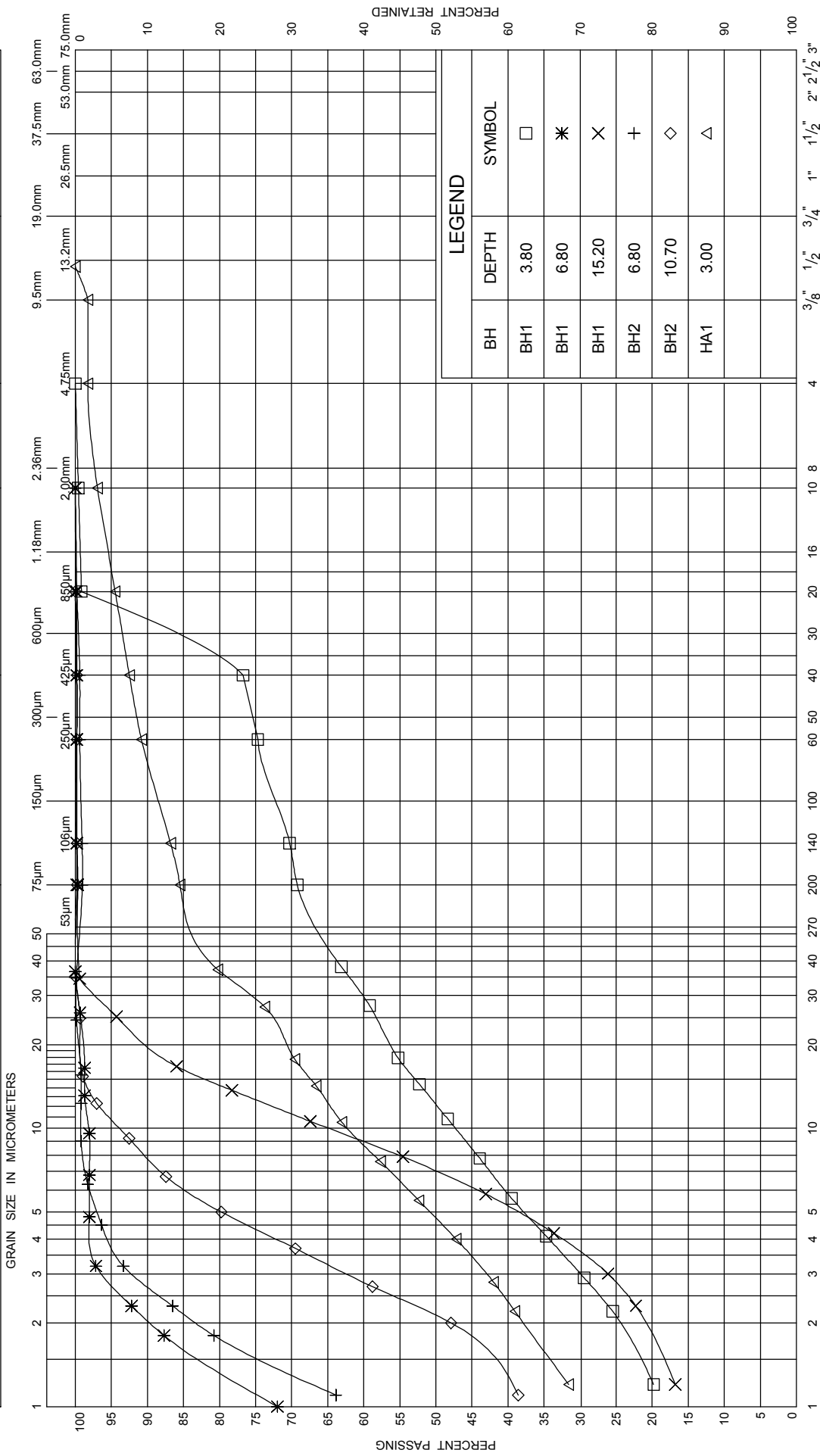
ENCLOSURE 6  
W P 5112-09-01  
HIGHWAY 11





UNIFIED SOIL CLASSIFICATION SYSTEM

CLAY & SILT		SAND			GRAVEL	
		Fine	Medium	Coarse	Fine	Coarse



MINISTRY SIEVE DESIGNATION ( Imperial )

GRAIN SIZE DISTRIBUTION  
CLAY

ENCLOSURE 7  
W P 5112-09-01  
HIGHWAY 11



